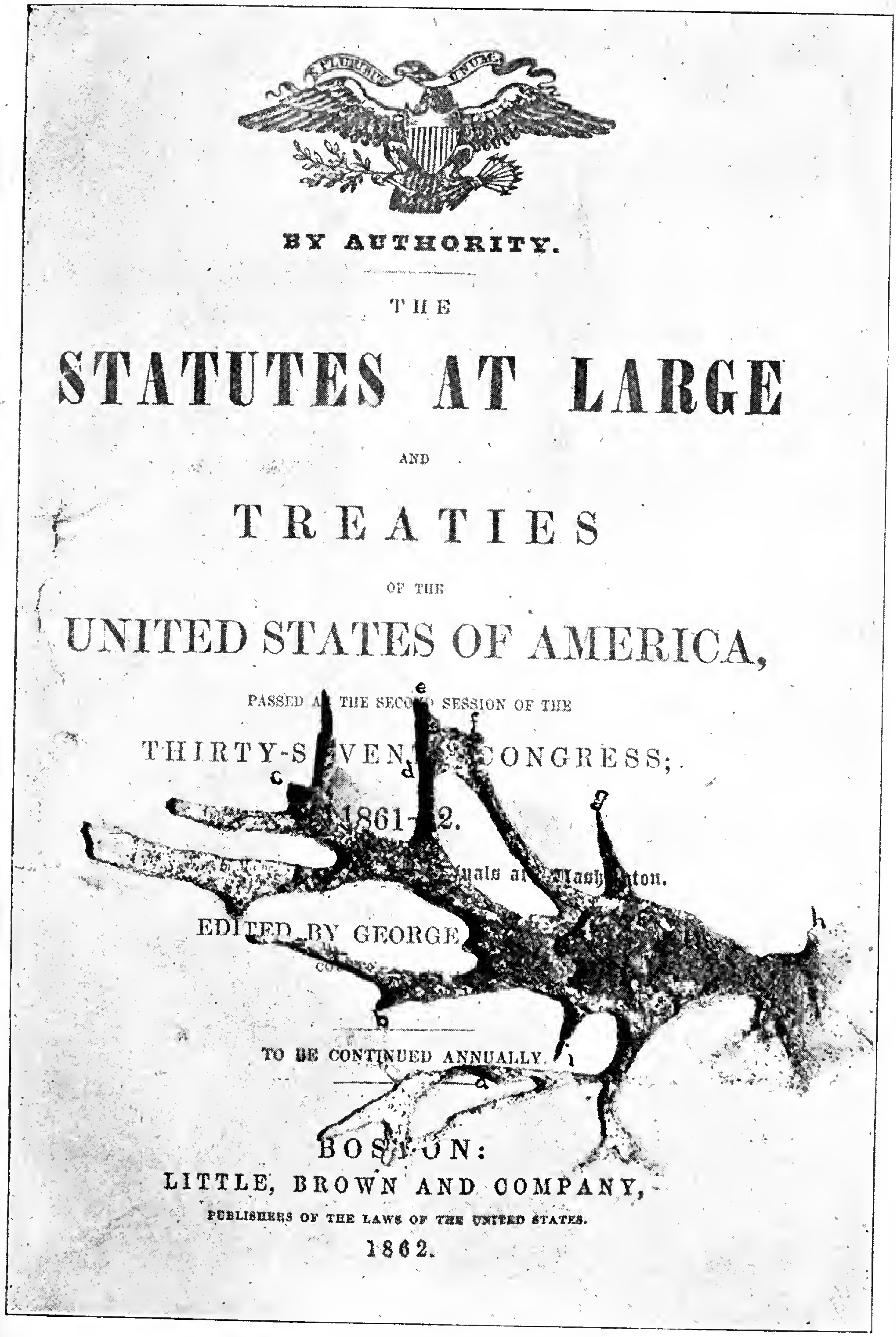

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APPENDIX.

LETTER OF TRANSMITTAL.

OFFICE OF STATE ENTOMOLOGIST,
URBANA, ILL., Dec. 26, 1894.

To His Excellency, JOHN P. ALTGELD, *Governor of the State of Illinois:*

SIR:—I have the honor to transmit herewith my eighth report as State Entomologist of Illinois, the nineteenth from this office. Although it applies nominally to the work of the years 1893 and 1894, it includes the results of some investigations made in 1891 and 1892. On the other hand, much of the work in progress during the two years just past, requires a longer time for its completion, and my report on it is consequently withheld until it can be presented in a finished form.

Respectfully submitted.

S. A. FORBES,
State Entomologist.

EXPERIMENTS FOR THE DESTRUCTION OF CHINCH-BUGS AS THEY EMERGE FROM FIELDS OF SMALL GRAIN AT HARVEST.

The fact that the first generation of the chinch-bug is commonly bred in wheat, barley, or other small grain from which it is obliged to escape on foot as the ripening of the grain deprives it of food, suggested long ago the idea that it might be trapped and destroyed in its passage from one field to another, and the economic literature of this insect contains many references to this possibility, and some accounts of practical experiments intended to take advantage of it.

Since the commencement of my own studies of the chinch-bug in 1882, there has been no outbreak of it in the vicinity of my office until this year, and field experiments of this description have consequently been difficult and expensive; but the appearance in the summer of 1894,of destructive numbers of the chinch-bug in a field of wheat on the University Experiment Station farm, near Urbana, gave the long-desired opportunity. I undertook, consequently, to determine by precise experiment the actual value of certain measures intended to prevent the passage of chinch-bugs from one field to another at this season, and to trap and destroy them *en masse* at the border of the infested field. These experiments are here reported, together with a few others of variable character made by farmers of my acquaintance and inspected by us from time to time through the season.

The two expedients used--the furrow and post-hole barrier and the coal-tar belt—have been before the agricultural public for many years, but the combination of them in a way to make each supplement the other has not before been made so far as I am aware. The results of this trial were most encouraging, and I cordially recommend the following procedure to farmers generally as the best now known for the midsummer destruction of chinch-bugs. It compares most favorably with the use of contagious diseases, being immediate in its action, resulting in the wholesale destruction of untold myriads of bugs, and being independent of the weather and other uncontrollable elements of the situation. Indeed, if this method were generally and uniformly applied with a persistence at all commensurate with the interests at stake—if it were made, that is, a common neighborhood practice to destroy chinch-bugs as they escape from grain fields at harvest time—I think that we should hear comparatively little of a demand for any other method.

As soon as the ripening of badly infested fields of small grain begins to compel the chinch-bugs to desert them, a strip of ground four to six feet wide should be deeply plowed, around the entire field where practicable, or at any rate along the side adjoining corn or any other crop liable to attack. This strip should then be thoroughly and deeply pulverized, first with a disk harrow and then with a brush, until it is reduced as nearly as possible to the condition of dust. Next, a short log eight or ten inches in diameter, or a triangular trough made by nailing two boards together and afterwards loaded with stone, should be dragged endwise back and forth in this strip, the driver riding the log or trough if necessary, until a deep groove or furrow has been made across the line of march of the chinch-bug host. The sides of the furrow should be dressed here and there with a hoe, as may be needful to make sure that no passageway out is left for the chinch-bugs which will presently accumulate in the bottom.

If the furrow has been well made, its dusty sides will prove impassable to the bugs which tumble into it, especially as these move at this time almost wholly on foot. If it is so placed that it is directly exposed to the sun, in very warm weather the great majority of the chinch-bugs caught in it will be speedily killed by the heat, the youngest succumbing first, but even adults finally perishing. Nevertheless, to insure their destruction, holes a foot in depth should be made in the furrow with a post-hole digger at intervals of about twenty feet, to serve as traps for the bugs. Here they will accumulate by pints and quarts or even by pecks in a place, according to the number in the traveling horde, and in these holes they may easily be killed with a little kerosene or coal-tar poured upon them. The post-hole digger may be conveniently used for removing them when dead and for dressing up the holes again.

As the myriads of bugs attempt to escape from the furrow, climbing its dusty wall again and again with desperate persistence, they will gradually lessen the slope by dragging down the dust as they fall back, and may thus in time make their way out. It is consequently necessary that the barrier should be continuously watched and occasionally rectified here and there with a hoe. After a time it will perhaps be most convenient to make another furrow parallel with the first, abandoning the latter or using it for the coal-tar strip presently to be described.

This furrow and post-hole barrier will work to practical perfection as long as the ground can be kept thoroughly pulverized, but even a slight shower of rain is sufficient to destroy it, releasing the imprisoned chinch-bugs and giving free passageway into the threatened field. As a safeguard against this contingency, a barrel of ordinary coal-tar should be brought to the field, together with a watering pot with a tubular spout and a dipper for dipping out the tar. If a slender line of coal-tar be poured along the bottom of the furrow, or on a hardened strip of ground outside, it will serve as a barrier to the progress of the bugs no less complete than that above described. When first applied it will soak speedily into the ground, but a hardened crust will thus presently be formed which will hold the tar until it slowly dries out. Along this strip post-holes may be made as before, in which the chinch-bugs will be caught even though the ground may be thoroughly wet.

If as a consequence of mismanagement or accident chinch-bugs succeed in crossing this barrier, they will accumulate upon the nearest corn, where they may be killed at slight expense by spraying or sprinkling the plant with the kerosene emulsion, made and applied as follows:

Dissolve one half pound of hard or soft soap in one gallon of water and heat to the boiling point. Remove from the stove and add two gallons of coal-oil, churning the mixture with a good force-pump for fifteen minutes. When the emulsion is formed, it will look like buttermilk. To each quart of this emulsion add fifteen quarts of water, and apply to the corn in a spray—preferably before 10 a. m. or after 3 p. m. The bugs should be washed off so that they will float in the emulsion at the base of the plant. A teacupful to a hill is generally sufficient, but the quantity must vary with the number of bugs infesting the corn.

The ascertained cost of material per acre of corn treated will be less than seventy cents where the plants are practically covered with chinch-bugs, and no more than thirty cents per acre where they are moderately infested.

In all this procedure continual vigilance and indomitable persistence are indispensable. A single man or boy will guard from eighty to one hundred and fifty rods of the barrier, but he must be in the field early and late. This method may seem troublesome and costly to the reader of this description, but the actual expenditure of labor and money is practically insignificant as compared with the loss of crops which may thus be prevented; and the hope that the chinch-bug can be mastered without labor, money, and pluck, must be dismissed, for the present at least, as an unrealized dream.

DESCRIPTION OF EXPERIMENTS WITH BARRIERS AND TRAPS.

Experiments 1, 2, and 3 were made on a small scale to test the efficiency of the furrow and post-hole method for the arrest and destruction of chinch-bugs while escaping from fields of small grain at harvest time. Numbers 4 and 5 were made to test the value of the coal-tar barrier, and 6 was a practical test of the two combined.

No. 1. This is a furrow experiment made July 10. A patch of wheat-stubble ground, 4x6 feet, was cleared off with a spade so that the surface was hard and smooth. Around this we dug up and pulverized a narrow strip of ground, in which a dusty furrow was made three inches deep inside and six inches outside, enclosing the entire patch. The outer face of this furrow had a slope varying from 50° to 60°.

At 2:10 p. m. we released in this enclosure over a pint of chinch-bugs* collected from corn adjacent, and observed their operations in the ditch. Probably one fourth of those collected were adults, the remainder being of various ages, mostly pupæ or in the stage immediately preceding. The adults were much the more active, the immature forms tending to accumulate and pile up on each other in the ditch.

The greater part of the chinch-bugs presently deserted the interior of the enclosure and attempted to escape from the ditch, forming a continuous belt in the bottom one to three inches wide and, where thickest, two or three layers deep. In their efforts to escape, the adult bugs persistently climbed up the outer face of the furrow again and again, without cessation, falling back each time to the bottom as the dust gave way beneath them, the result being finally to accumulate a slope or talus of dirt at the bottom of the furrow of an incline sufficiently gradual to permit them to climb it easily. In this manner they slowly advanced upward, until in an hour and a half from the beginning of the experiment a few escaped at one corner by climbing up a kind of ladderway of small clods and roots projecting from the surface. Not over fifteen or twenty thus released themselves, when the clods were undermined and fell, breaking the passageway.

An hour and three quarters from the beginning, a post-hole was made in the furrow at one end of the enclosure. The chinch-bugs nearest it presently fell in, and as others advanced to take their places—apparently impelled by the pressure from their neighbors—they also were trapped. The impulse was thus gradually passed along the struggling line until within a few minutes there was a definite movement of the entire body of chinch-bugs for about three feet on each side of the hole towards and into it. By 4 o'clock probably half of the chinch-bugs in the enclosure had been trapped. This movement had so greatly diminished the progress of those attempting to ascend the side of the furrow that at this time they had nowhere generally advanced beyond an inch below the upper edge. Without the post-hole it is likely that they would have begun to make their escape in considerable numbers in about two hours from the time the experiment began.

We collected and brought to the laboratory from the post-hole trap and from the furrows about one pint of chinch-bugs, leaving the remainder in the enclosure. Next morning the greater part of these—probably all except the adults—were dead in the bottom of the furrow, killed by exposure to the sun.

No. 2. July 11, two parallel furrows twenty-five feet long were made in a thoroughly pulverized strip of ground in wheat stubble by dragging an eight-inch log back and forth through the dirt. These furrows were connected at the ends by transverse furrows of the same character, thus enclosing a strip of solid, smooth

*The numbers of chinch-bugs used in these experiments were determined by counting those in a given measure, 10 c. c., a pint being thus ascertained to contain about 132,500, a quart 265,000, and a bushel about 8,480,000.

ground between them a foot and a half across. The furrows were two inches deep inside and five inches outside, the outer slopes varying from 40° to 54° 30′.

We collected a quart and a gill of chinch-bugs (estimated number 300,000) from adjacent corn, and placed them on the strip enclosed by the furrows, distributing them the whole length of the plot. A few adults flew at once, and several others made the attempt, as, indeed, adults had occasionally done the day before. In twenty minutes probably nine tenths of them were dead upon the ground, evidently from the heat of the sun. Most of them had died on the hard earth between the furrows without reaching the latter. Two thirds of those in the furrows at this time were adults. Those dead from the heat were nearly all young, but an occasional adult was seen among them.

The principal movement of the imprisoned chinch-bugs was at first to the north, into the furrow on that side, but presently they abandoned their attempt to scale this slope, and all remaining alive resorted to the south furrow, collecting chiefly at two points. This was evidently due to the greater heat of the north furrow on account of its more direct exposure to the sun. As the chinch-bugs work at a somewhat steep slope they gradually undermine it, leaving an overhanging ledge which they cannot scale, but which they gradually work down in their efforts to climb the bank.

The temperature of the earth, determined by simply laying a thermometer on it in the sun, was 116° Fah. at 11:05. If the thermometer was barely buried in the dust it was 122°. The air temperature at the same time was 91°. Sky cloudless, and a gentle wind.

To verify the effect of the hot earth and sun upon chinch-bugs, an additional pint was collected and put into the small enclosure used the preceding day. These were killed as above, and almost as rapidly. Wherever a rootlet or any other solid substance projected above the surface it was thickly covered with chinch-bugs, and a stick of any kind thrust in among them would be immediately blackened by them, as they crawled upward, collecting at the top and dropping off as they crowded each other outward. Taking advantage of this fact, a small trap was arranged by inclining sticks over a dipper of coal-tar. Two or three fluid ounces of chinch-bugs were collected in this way in the course of half an hour. This is, however, a very much less rapid method than the post-hole trap.

We estimated that at the rate of action of the chinch-bugs in these furrows a single man could certainly supervise eighty rods along the edge of a field, and probably twice as great a distance.

No. 3. July 12, a quantity of chinch-bugs was placed in the large enclosure described under experiment 2, the first lot at 6:25 a. m. and a second at 7, and a coffee can was sunk in the furrow at one end of the plot.

At 7:40 chinch-bugs placed in the southern furrow, and a belt of coal-tar poured along the middle of the enclosed space. Day clear and rather windy. At one place where the slope was 58°, chinch-bugs began to escape almost at once; but by steepening the furrow at this point with a hoe, we confined them permanently, only a very few escaping by making here and there a temporary passageway which permitted now and then one, at long intervals, to emerge. Such passageways were presently undermined, and the number escaping was entirely insignificant.

Chinch-bugs began to collect in the can as soon as they were placed in the furrow, but the angle of the furrow near it arresting them, a second one was placed in the middle of the furrow. Into this can they fell in quantity, presently marching towards it from the right and left, thinning out the crowd in the furrow for a distance of nine feet on one side and ten to twelve feet on the other, until by 9 o'clock the attack was practically broken all along the line by the capture of nearly all the bugs.

At 6:45 the temperature of the ground, the thermometer being lightly covered with dust, was 79°; that of the air, in the sun, 82°.

At 8:15 the temperature of the dirt, taken as above, was 97°, and that of the air, 85°, the thermometer erect in the sun.

At 9, chinch-bugs had begun to die where most exposed to the sun. Dirt was here 108°; air, 87½°, with thermometer erect.

No. 4. July 12, a patch of wheat stubble was cleared off, as in experiment 1, and at 7:30 p. m. a belt of coal-tar two inches wide was put down, forming an oval enclosing a space twenty-five feet long by two feet across. Post-holes about ten inches deep were dug at either end with a common post-hole digger. Coffee cans, about six inches in diameter and seven or eight inches in depth, were placed in the post-holes so that the entrapped chinch-bugs could be easily removed and measured.

At 7:45 p. m. half a pint of chinch-bugs was distributed over the hard smooth surface within the enclosure. At first they went in all directions, and many ran headlong into the tar and were destroyed; but the greater number were more deliberate, and moved up and down the tar line without making any attempt to cross it. By 7:50 a large proportion had passed from the middle of the enclosure to the edge of the coal-tar, principally on the south side, but forming a belt around the entire enclosure, the general movement being eastward.

At 8 o'clock they were less active and were most abundant at the ends of the oval, but very few had fallen into the post-holes. There was no disposition to climb rootlets or other projections above the surface.

At 8:30 they were still less active, and were collecting together in masses on small lumps of earth and in depressions on the surface. No general movement observed at this time. About fifteen hundred chinch-bugs were removed from each can. They were most abundant in the east and west ends and along the south side of the oval. The slightest disturbance, such as the movement of a finger on the ground in their midst, caused the greatest confusion among them.

The sky was clear, with a gentle breeze from the west. Temperature of air at 7:30 was 82°, the thermometer held erect; surface, 82°, as determined by simply laying the thermometer on the ground.

At 8:30 both air and surface were 74°, observations being taken as above.

At 5 a. m., July 13, the young were more active than the adults, and a great many bugs were still collected on lumps of earth and in depressions on the surface. A few were crawling and falling into the post-holes, about as many having been trapped in eight hours and a half during the night as had been caught the previous evening in three quarters of an hour.

At 6 o'clock the temperature of the air was 74°, the thermometer erect and about four feet above the surface. The soil temperature was 78°, thermometer slightly buried. The chinch-bugs were now very much more active, and were moving in considerable numbers toward the east end of the oval, about six times as many (9,000 in round numbers) having collected in the post-hole at this point since 5 o'clock as had been entrapped during the entire night. Their activity steadily increased, and in a few moments there was a regular procession fourteen feet long moving to the eastward along the tar line towards one end of the oval, and to the westward for a distance of six feet towards the other, leaving an intermediate space of about five feet where there was no appreciable tendency in either direction. Very few bugs passed the coal-tar, although it was dry and could easily have been crossed. It served practically as an impassable barrier.

At 9 a. m. the temperature of the air was 85°; surface 112°. The oval was almost entirely freed from chinch-bugs, the most of them having fallen into the post-holes. Two thirds of the entire lot that had been placed in this enclosure the previous evening were taken from the cans, the great majority having fallen in since 6 a. m. If the three thousand chinch-bugs taken from the post-holes at 8:30 p. m. the preceding day and those still remaining within the oval are taken into consideration, it is clear that only a very small number escaped.

No. 5. July 13, an experiment similar to No. 4 was made on an oval half as large, with post-hole in one end. Slight rain at 2 p. m., just enough to settle the dust. Sky cloudy, with light breeze from southwest; temperature of air 90°; surface 87°.

At 2:30 p. m. renewed barrier by pouring coal-tar over line used the day before, for a distance of twelve feet on either side, and across the ends; but at the east end the tar was poured on the ground, as no line had been previously made at this point. One gill of chinch-bugs was distributed on the surface of the hard ground enclosed. They were very active, and in ten minutes the center of the oval was comparatively free, the insects forming a band next the tar line around the entire enclosure. By 3 p. m. the bugs had mostly collected on the south side and in the ends, being most abundant in the east end, where they were very active. The general movement at this time was to the eastward, but many were tumbling into the can at the west end. A strong wind from the southwest blew many insects over the line.

Outside the tar line, myriads of young bugs just from the egg were moving southward in the direction of the adjoining corn (C, Pl. II.), nearly covering the ground in many places. Not a single insect attempted to cross the tar, although in their confusion they scrambled about in all other directions; but where no barrier intervened they passed rapidly along towards the corn.

Two thirds of the bugs within the oval had collected at either end by 3:30 p. m., and about two thousand had fallen into the can.

At 4:30 p. m. the barrier was in good condition except at one place where the coal-tar had been poured over the loose ground and was now getting quite dry. A few insects attempted to cross the line, but either retreated or went pell-mell into it and were destroyed. One third of the entire lot had collected in the east end, and the others were scattered about the oval. About five thousand were taken from the can, and the experiment was left over night.

July 14, at 9:30 a. m., of the twenty-one thousand bugs left in the oval the previous night, less than two thousand remained, one half of these being in the can. The remainder had escaped during the night and early morning through a passageway at the east end where the tar had become dry, and where the wind had blown fine particles of dirt over the surface, completely covering it.

At 10 a. m., sky clear and a gentle westerly breeze. Temperature of air 84°; surface 106°; soil 117°.

No. 6. July 10, a strip of ground between the spring wheat (B, Plate II.) and corn (C) three feet wide, was thoroughly and deeply pulverized by means of a harrow-toothed cultivator, and a twelve-foot plank drawn endwise, the driver riding the harrow or plank when necessary. Next, a log about six feet long and eight inches through was dragged endwise back and forth in this strip, the driver riding it, until a deep furrow had been made. The sides of the furrow were then dressed up here and there with a hoe.

Similar furrows were made in the fifth and sixth rows, and a narrow line of coal-tar was poured along the bottom of the furrow in the latter row, from an ordinary two-gallon sprinkler without the nozzle. On the first application one gallon of tar was sufficient for a line ten rods long, and thereafter for about twenty rods. The tar very soon formed a crust, but remained in good condition, and completely checked the advance of the chinch-bugs for twenty-four hours or longer.

Holes about a foot deep were made in each furrow with an ordinary post-hole digger at intervals varying from ten to twenty feet, according to the abundance of the bugs.

A strip of winter wheat (A) of about four and a half acres, badly infested with chinch-bugs, was cut June 27 to July 3. The bugs then attacked a narrow strip of spring wheat (B),—about one rod wide, running the entire length of the field,—which they completely ruined. This was cut July 7 and burned over the following day. Many bugs were destroyed, but the great majority of them moved into adjacent corn (C), blackening the stalks in the first two or three rows.

The furrow beside the first row did not check their advance to a very great degree, from the fact that it had been defaced and broken down to some extent, and was strewn with straw and other rubbish from the wheat. The furrow beside the fifth row and tar line by the sixth, however, completely arrested their advance and practically kept them confined to the first five rows, where a quart or more could have been easily collected in a few minutes by jarring the stalks and catching the bugs in a pan.

The insects worked away in the furrow, endeavoring to escape much as described under experiments 1 and 2. An occasional one made good its escape by means of a projecting rootlet or the rubbish strewn about, but was repelled by the tar line in the next row, which seemed to be regarded as an impassable obstacle. In both cases there was a general movement up and down the lines, and the bugs were constantly falling into the post-holes, a pint or more being entrapped in each, where they were killed with a strong mixture of kerosene and water or by a little coal-tar poured upon them.

In the furrows where the bugs were directly exposed to the snn, a great many were killed by the extreme heat, the tender larvæ succumbing first, but even adults dying finally.

These furrows were dressed up here and there from day to day with a hoe, as was necessary, and the tar line was renewed about every twenty-four hours. A slight rain fell July 13, just enough to lay the dust, and the furrow in the fifth row no longer restrained the marching horde. The ground was covered with young bugs, either in the pupa stage or the moult just preceding, and their advance was southward toward the center of the field. The tar line, however, remained unaffected, and proved the same impassable barrier to the advancing hosts as when first put down. The bugs ran restlessly up and down the tar front, tumbling into the post-holes, where they were finally destroyed, or being speedily killed in the furrows by the excessive heat as they ran here and there over the ground.

The insects made good their advance in the eastern half of the field, where no barriers obstructed their course, and completely covered the corn as far as the ninth and tenth rows inward. The average yield in such places was reported at the end of the season by the farm superintendent as about twenty per cent. less than that of corresponding rows in the upper part of the field, where the barriers had been used. The chinch-bugs, on the other hand, were originally far less numerous in the wheat adjacent to this part of the field than at the other end, where they were destroyed as described above.

The five following (Nos. 7–11) are farmers' barrier experiments, made to arrest the advance of chinch-bugs as they moved from wheat to corn in late June and early July.

No. 7. Made by Mr. Samuel Bartley, of Edgewood. A narrow strip of ground in corn along the side adjoining wheat was deeply pulverized, and through this a deep furrow was afterwards made by dragging a log endwise. The sides of the furrow were as steep as they could be made without caving in. The wheat was cut the following day (June 28) and the chinch-bug hosts started for the corn field. Their advance was completely checked for a time, and they accumulated in great numbers in the furrow.

Mr. Marten visited this field June 29. The furrow was then in fair condition, and contained myriads of bugs endeavoring to escape. There were many insects in the wheat stubble and in a narrow strip of grass between the wheat and corn, but comparatively few on the latter crop.

No provision had been made for the destruction of the bugs in the furrow, and a slight rain June 30 breaking down the sides, in a short time the traveling horde made good its escape, almost completely destroying the corn as it advanced.

No. 8. This is a furrow experiment, made by Mr. James Smith, of Farina. About June 28, just before wheat harvest, Mr. Smith abandoned his contagion box and plowed furrows between wheat and corn, wheat and oats, and oats and corn. The furrows were made about eight inches deep with a shovel plow. A log drawn by one horse was dragged back and forth through these furrows for about a week. Myriads of bugs were crushed, and many died from exposure to the heat as they were confined in the furrows. Very few bugs crossed these ditches into the corn, and less than a quarter of an acre was injured by their attacks. A slight shower had fallen soon after the log was started, stopping operations for a short time, and a considerable number of chinch-bugs then passed the furrow, but the ditches were opened again as soon as possible, and the dragging was resumed.

At the time of Mr. Marten's visit, July 11, the log had not been used for several days, and the bugs were crossing the ditches in great numbers and were accumulating on the corn, where they did considerable damage later in the season.

No. 9. This is a barrier experiment conducted by Mr. C. M. Filson, of Xenia, in corn adjoining wheat which was cut June 15. The chinch-bug horde came into the corn immediately and ruined ten or twelve rows. Mr. Filson thoroughly pulverized a narrow strip of ground in the twelfth row on the south side of the field, and along the outer edges of the east and west sides, and through this a log was dragged until a deep furrow was made the entire length of the three sides. Post-holes were then dug in the furrows about ten feet apart, into which the traveling bugs fell in great numbers, where they were destroyed with kerosene emulsion or by crushing. While the furrows were in process of construction quite a number of bugs succeeded in crossing the ditch and accumulated on the first two or three rows beyond. These were destroyed with kerosene emulsion, applied by means of a brush-like broom, made of prairie grass, dipped into a pail containing the emulsion and shaken over the bugs on each hill. Many fell on the ground during this operation and were killed by the emulsion. The furrows were kept in good condition for two weeks. The progress of the incoming horde was practically arrested, and very few bugs were seen in the field the latter part of the season. The corn yielded about twenty bushels to the acre, which was more than the average for that neighborhood.

A field of corn, adjoining this same wheat field on the south, in which no measures were taken to arrest and destroy the chinch-bugs as they came from the wheat, was ruined, excepting only a small part which was thought worth cutting for fodder.

No. 10. Mr. H. H. Mayo, of Falmouth, in Jasper county, made a deep furrow in a well-pulverized strip of ground in corn. Wheat adjoining was cut about June 23, and the bugs entered the corn in great numbers. The furrow completely checked their advance for a time, and myriads of young were seen dead in the furrow from exposure to the extreme heat. A slight rain fell shortly after the wheat was cut, after which the furrow was not reconstructed, and the pests had free passageway into the corn. Over four acres were completely destroyed in a few days, and the attack spread throughout the twenty acres, from which less than half a crop was taken.

No. 11. This is a barrier experiment made by Mr. Thos. B. Wilson, Sr., of Greenup, in corn adjoining wheat. The wheat was cut June 25, and the chinch-bugs made rapid advance into the corn. The ground between every fifth row from the edge, for a distance of twenty rods, was thoroughly pulverized and deeply furrowed June 26. The bugs collected in these furrows in great numbers, and were killed by dragging a log back and forth. This was kept up for eight days. The first fifteen rows were entirely destroyed, owing to the fact that the insects accumulated here before the furrows were made. The corn in the remainder of the field was far better than the average in the county, and yielded fifty bushels to the acre.

ON CONTAGIOUS DISEASE IN THE CHINCH-BUG (*Blissus leucopterus*, SAY)*.

ON THE RELATIONS OF ECONOMIC ENTOMOLOGY.

Economic entomology is most commonly thought of as a division of entomology; and so it is, indeed, but not in the sense in which that statement is most likely to be taken.

An entomologist as such is interested primarily in the study of insects, and other matters come into his field only incidentally and as a help to an understanding of his entomology; but the center of interest to the "economic entomologist," so called, is not the insect itself but its relation to the material well-being of man.

There is another division of biological science, little known to the general public by its name as yet, and but lately distinguished as a separate subject, but which is now commonly called *œcology.* It is the science of the relations of living animals and plants to each other as living things and to their surroundings generally. It deals with the ways in which heat and light, moisture and drouth, soil and climate, and food and competitors and parasites and predaceous enemies, and a long list of agencies additional, act upon living things, and the ways in which these living things react in turn; it includes, in short, the whole system of life as exhibited in the interactions between the plant or animal and the environment, living and without life. It is a very comprehensive, complicated, and important subject; how comprehensive and important we see at once when we learn that the whole Darwinian doctrine belongs to it on the one hand, and that all agriculture depends upon it on the other. It covers, indeed, the whole field of active life and all forms of matter and energy as affecting living things in any way.

Economic entomology is, of course, a division of this science of œcology and may be exactly defined as entomological œcology applied to economic interests. The economic entomologist is thus essentially an œcologist, engaged directly in a study of the relations of insects to the pursuits and welfare of mankind, and indirectly in a study of their relations to the general system of living nature at large.

*For general summary of economic values and results, see p. 26.

In practice, indeed, it is to this system of living nature as affecting insects, and through them as affecting man, that he must give his principal attention; for the more the scientific œcologist studies the natural order of life the higher is his respect for the scheme of adaptations and adjustments which it everywhere exhibits, the more apprehensive he becomes of the consequences of ignorant interference with the settled workings of this system, and the more clearly he sees that, since much interference is inevitable, its consequences must be clearly understood, and means must be devised to correct such reactions as are likely to have a harmful issue.

The study of œcology is thus to the economic entomologist what the study of physiology is to the physician. Human interference with the natural order of plant and animal life gives rise to reactions which correspond closely to those of bodily disease. What physiology is to medicine, that œcology is to economic entomology. As the old medicine was chiefly a matter of drugs and empirical dosage, so economic entomology was not long ago almost wholly a matter of insecticides and mechanical methods of destruction. The new economic entomology, on the other hand, like modern medicine, seeks diligently, first, to avoid all unnecessary disturbance of the normal play of life, and, second, to direct the powers of nature herself, so far as possible, to the correction of such disorders as are nevertheless likely to arise.

PARASITISM OF INSECTS.

Many of the natural checks upon the inordinate multiplication of insects, and thus upon the disturbing consequences of such excess, are beyond our present control or influence,—those interposed by the weather, for example,—but one of the most powerful of them all, may apparently be brought more or less completely under our control. When all other restraining agencies fail or prove too weak to check an insect outbreak, parasitism by other insects or by plants is one of nature's last and sovereign expedients; and this remedy never fails finally to reduce the too prolific species to its proper place.

To gain control of this great natural agency, to apply it to the correction of the disorders which we have ourselves induced, and even to improve by its means and for our purposes the natural œcological system of the world, is one of the present problems of the economic naturalist. It is along this line that the greatest advances in modern medicine have been made,—the greatest the world has ever seen in this oldest of the biological sciences,—and it is along this line that the economic entomologists of this country and of Europe are now beginning to work, in the hope of doing for the labor of men something like what has been done by the physician for their lives.

The most destructive parasites of insects may be divided biologically into three principal classes—insects, Protozoa, and fungi.

They may be otherwise divided, from the practical standpoint of economic utilization, into two groups; those capable of growing in or on living insects only, and those which may be grown artificially by using inanimate substances as a culture medium. The difference between these latter groups is especially important in practice, because the quantity of those parasites which cannot be artificially grown can only be increased by infecting living insects themselves, while those of the other class can usually be readily and rapidly increased at will by the use of suitable media and proper culture methods. Insect and protozoan parasites and some of the higher parasitic fungi belong to the first of these classes; while bacteria and the other higher fungus parasites, including the species to which this article is devoted, belong to the second class—that is, to those capable of multiplication by artificial methods on gelatinous and other inanimate mixtures.

As economic entomology has hitherto been pursued almost wholly by mere entomologists, the insect parasites of insects have received by far the greater share of attention, and their protozoan parasites have scarcely been studied at all except in connection with the most destructive disease of the silkworm, commonly known as *pébrine*. The fungus parasites of insects generally, on the other hand, have been studied until recent years almost wholly by botanists, interested in them simply as plant species of peculiar habit and rarely pushing their studies over to the field of practical application.

THE CONTAGIOUS DISEASES OF INSECTS.

The contagious diseases of insects are all cases of parasitism, and are due most commonly to parasitic plants (bacteria and mold-like species) of minute size and of an enormously high reproductive rate. Bacterial parasites commonly infest the insect by way of the alimentary canal, while the parasitic molds attack it from without. To this second class belong the several species of disease-producing fungi specially dealt with in this report. They may be described as minute molds which germinate and grow on the living insect, thus causing it to "mildew," as we may say, while it is yet alive. They start from little spores or "germs" of microscopic size, capable of being wafted everywhere on the lightest breeze, and sprouting on the moist surface of the chinch-bug or the cabbage worm as grass seed sprouts on the soil; and as they sprout they send into the body of the infested creature their tiny rootlets and speedily kill it by feeding on its blood. After the death of their host these little plants continue to grow, penetrating and disorganizing the tissues of their victim; and if the air is moist they send tiny white threads out through the body wall, soon completely imbedding the insect as if in a delicate tuft of finest cotton. On these little threads new spores will form in unnumbered myriads, and thus the dead body becomes a center of contagion to healthy insects.

The bacterial diseases of insects attack first the cellular lining of the alimentary canal and afterwards penetrate to the blood. Disturbance of the digestive functions is thus the primary difficulty, and the final result is a very rapid *post-mortem* decay of all the fluids and tissues, the body speedily becoming a filthy semi-fluid mass.

THE BEGINNINGS OF KNOWLEDGE AND THE PROGRESS OF INVESTIGATION.

Contagious insect diseases have been vaguely known for many centuries those of the domestic insects, bees and silkworms, first and most precisely. Aristotle's observation that the honey-bee is subject to diseases (History of Animals, VIII., 26) probably had reference to one or both of those now called dysentery and foul-brood, both contagious and both due to bacterial infection. Towards the close of the seventeenth century the contagious maladies of the silkworm so ravaged the hatcheries of France that despairing silk growers were only prevented from destroying their mulberry plantations by official orders to the contrary, and twice at least in the following century a like calamity fell upon them.

The various silkworm diseases were not at first discriminated; but muscardine was intelligibly described in 1763, was known as contagious in 1819, as characterized by a fungous efflorescence in 1820, and as capable of transfer to caterpillars of other species in 1829. Its fungus was studied botanically and described as a Botrytis in 1835, transferred by inoculation to other silkworms in 1836, and found spontaneous among wild insects of different orders in 1839. By these discoveries the foundation was laid thus early for an economic method applicable to the destruction of injurious species by infection with spores of the fungus of muscardine.

The first species of Entomophthora recognized was the common house-fly fungus, *E. muscæ*, described in 1829.

Foul-brood of bees was called by that name at least as early as 1767, but the first bacterial insect disease *distinctly recognized* as such (in 1858) was *flacherie* or *schlafsucht* of the silkworm, conclusively studied by Pasteur in 1868, and by Ferry de la Bellone and others in 1876 to 1879.

The first of the plant parasites of less familiar insects to attract attention were those which produce a conspicuous rod-like or club-shaped growth from the body after death, and many observations on these peculiar growths were published during the eighteenth century. The common club-fungus (Cordyceps) of our American white grub is an example.

Parasitism of silkworms by Protozoa (Sporozoa), causing what is perhaps the most destructive of all contagious insect diseases (*pébrine*) was recognized by Leydig in 1857. Balbiani's studies of the life history of this parasite in 1866 and 1867 and Pasteur's practical researches in 1867 and 1868 put our knowledge of this disease also on a firm foundation.

The possibility of utilizing the fungus parasites of insects for the destruction of injurious species was greatly enhanced by the discovery of methods for the pure culture of fungus species on artificial substances. These methods with bacteria resulted from a prolonged controversy over the doctrine of spontaneous generation which ran through several years about the middle of this century. General culture methods with higher parasitic fungi were devised between 1860 and 1870 by botanists—Tulasne, De Bary, and others—engaged in a study of the life histories and metamorphoses of fungi.

It will thus be seen that by 1870 everything had been made known which was necessary to a scientific foundation for economic experiments with at least four great classes of fungous and sporozoan diseases of insects; and a very pointed suggestion of their utilization for the destruction of injurious species was in fact contained in observations on the muscardine of silkworms published thirty years before. This idea had indeed been already several times definitely expressed, and some rather crude practical experiments had been undertaken by Bail in Germany, unfortunately based in large measure on mistaken ideas of the relationships of different fungus forms.

THE SUBJECT IN AMERICA.

The economic entomologists of America were all this time seemingly without knowledge of these European observations and investigations, being perhaps too strictly entomological to have access to the proper sources of information; and when Dr. Henry Shimer, of Carroll county, Illinois, published in the Proceedings of the Philadelphia Academy of Sciences for 1867 a detailed account of his observations on the disappearance of a highly destructive outbreak of the chinch-bug in 1865 in consequence of the appearance and rapid propagation among them of what we now recognize as unquestionably a form of muscardine, neither he nor any other of our entomologists understood the occurrence. Shimer himself regarded the disease as an "epidemic, doubtless produced in a measure by deficient light, heat, and electricity, combined with excessive humidity of the atmosphere, whereby an imperfect physical organization was developed." "The disease was at its maximum," he says, "during the moist warm weather that followed the cold rains of June and the first part of July. The young chinch-bug spent a great portion of its time on or near the ground, where its body was colder than the atmosphere, hence, upon philosophical principles, there must have been an excessive precipitation of watery vapor in the bronchial tubes. These are the facts in the case, but in the midst of the great obscurity that envelops epidemic diseases among men it would be only idle speculation to attempt to define the cause more definitely than the physiological laws already observed seem to indicate." Concerning the fungous accompaniments of this disappearance he only says: "Plenty of dead bugs may be seen everywhere lying on the ground, covered with the common mold of decomposing animal matter, and nothing else, even when examined by the microscope. Even of those that migrated to corn fields a few weeks ago in such numbers as to cover the lower half of the corn stalks, very few are to be found remaining alive; but the ground around the base of the corn hills is almost literally covered with their mouldering, decomposed dead bodies. This matter is so common as to be observed and often spoken of by farmers. They are dead everywhere, not lying on the ground alone, but sticking to the blades and stalks of corn in great numbers, in all stages of their development, larva, pupa, and imago." It seems likely from his whole account that both Sporotrichum and Entomophthora were present among these chinch-bugs, but his description is too indefinite to enable one to say with any certainty.

Shimer's entomological contemporaries of that day, Walsh of Illinois and Riley of Missouri, failed to suspect fungous infection as a cause of these phenomena, ridiculed the idea of a chinch-bug disease, and characterized his reasoning as "pure assumption, speculation," etc. It was not until ten years afterwards that Dr. Cyrus Thomas, then State Entomologist of Illinois, suggested the idea of a fungous disease as an explanation of the occurrences reported by Shimer. "Although the plague among the bugs," he says, "appears to be somewhat extraordinary, yet it is in accordance with facts ascertained in reference to other insects, and as Dr. Shimer is both a competent and reliable authority, we accept his statement as correct, and believe with him that it was owing as the originating cause to the damp season. But we are inclined to believe that the moisture gave rise to a minute fungus as the direct cause of the death of the chinches."†

The first definite suggestion among us of the possibility of the economic use of fungous insect disease was made by the well-known coleopterist, Dr. J. L. LeConte, in 1873, when, in a public address,‡ he recommended "careful study of epidemic diseases of insects, especially those of a fungoid nature, and experiments on the most effective means of introducing and communicating such diseases at pleasure." Referring in 1880 to this earlier recommendation, he says that he had in mind the work of a "well-trained mycologist, skilled in the recognition of microscopic forms, acquainted with ferments and their methods of growth, familiar with the protean forms of zymosis, so far as they have been traced to organic germs—in few words, a first-class scientific student, who, after careful investigation of the fungus-killed insects brought to him by the 'practical' entomologists, shall inform the latter of the nature of the fungi, whether they are transmissable or fixed in structure, how they can most advantageously be cultivated, and in what vehicle they can best be distributed when needed."§

* Am. Ent. Vol. I., p. 175.

† Bull. 5 U. S. Ent. Comm.

‡ Hints for the Promotion of Economic Entomology. Proc. A. A. A. S., 1873, Pt. 2, p. 22.

§ Can. Ent. Vol. XII., p. 127.

The first actual experimental operations on this subject in America were based, unfortunately, upon the mistaken ideas of Bail with respect to the interchangeable relations of the common house-fly fungus, the common molds, the yeast plant, and the fish fungus (Saprolegnia), which DeBary referred to in 1884 as a "subject for the history of botanical error." In 1879, Dr. H. A. Hagen, Curator of Entomology to the Museum of Comparative Zoölogy at Cambridge, Mass., began to write on the use cf yeast as an insecticide, upon the supposition that insect diseases might thus be provoked through a transformation of the yeast plant into a parasitic fungus. This theory broke down, however, under the practical tests made by Hagen himself, and by Riley, Prentiss, Smith, Cook, Willet, and others, during the years 1879 to 1882; but observation of insect disease was evidently stimulated by the general attention which the discussion of Hagen's article attracted, and a number of scattered notes of miscellaneous observations published during the years next following will be found included in the bibliographical list appended to this paper. As none of these minor observations have thus far led to practical experiments, they need not be further discussed in this place.

The only experimental work with the fungi of insect disease since done in this country has grown out of studies of the *flacherie* of caterpillars, especially of the common cabbage worm (*Pieris rapœ*), and of three species of fungous parasites of the chinch-bug—all first distinguished as parasites of that insect and all first extensively studied in that relation by the writer at the Illinois State Laboratory of Natural History. The cabbage-worm disease, which I have since identified with *flacherie*, was first noticed in this country by Riley and his assistants at Washington,* and reported by him in 1880, although not recognized at the time as a contagious malady. It did not appear in Illinois until the fall of 1883, at which time I began my investigation of it, making studies of the disease in the cabbage worm itself, cultures of bacteria from the alimentary canal and body-fluids of sick larvæ, and attempts to convey the disease to distant points by sending dead and diseased caterpillars as an infection material.† Similar studies were made by me in 1883 and 1884 of *flacherie* of the apple and walnut caterpillars (*Datana ministra* and *D. angusi*), infection experiments in these cases being made by spraying the food of healthy larvæ with fluid cultures of the bacteria found in those suffering from disease.

The preliminary steps had been taken also by the writer before this time—that is in the fall of 1882 and 1883—towards experimental work with the contagious diseases of the chinch-bug. Cultures were made of bacteria then first found in certain cœcal append-

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* Evidence of the occurrence of this affection of cabbage worms in Europe will be found in the following statement taken from Curtis's "Farm Insects," 1859, p. 96: "On the 20th [September, 1841] they [larvæ of the 'white cabbage-butterfly'] appeared healthy, but inclining rather to a yellow color; it rained during the night, and on looking at them in the afternoon of the following day, I saw they had removed to a leaf, to which they stuck by four of their hinder legs, and, to my surprise, they were of a dirty color, and rotten, the skins being lax, and lying just as the wind blew them about. I found they only contained some cream-colored fluid, a portion of which was scattered upon the leaves."

† These were the first successful experiments of which I have seen any record for the conveyance of the diseases of injurious insects by this method of contagion, which has since come into very extensive use in connection with the chinch-bug.

ages of the alimentary canal in that insect, and observations were recorded of the occurrence on the chinch-bug of an Entomophthora, undoubtedly the frequent cause of its death in the field. The subsequent discovery that the chinch-bug bacterium (*Bacillus insectorum*) is normal to that insect, occurring always in the intestinal cœca, and that similar bacteria are always to be found in the corresponding appendages of a large number of other species of the higher families of bugs, finally put a stop to experimental work on this supposed bacterial disease of the chinch-bug. The subject is not yet worked out, however, and will repay further study.

To the Entomophthora observed by me in 1882 I added in 1887 another fungus parasite of the chinch-bug, which has proven far more destructive than the former. It is closely allied to the genus Botrytis, and would be placed by some botanists under that genus now. It is at present known, however, in American economic literature as *Sporotrichum globuliferum*, Speg.

First found to infest the chinch bug, as above, in 1887, and first published in that relation by me in October, 1888, it was first observed in Illinois during the late summer and fall of 1888 to cause widespread destruction of that insect in the field. It was first certainly conveyed to healthy chinch-bugs in Kansas by Prof. Snow in July, 1889, by confining these insects with dead and diseased specimens; and the chinch-bugs thus infected were thereupon used there for the propagation in the field of the disease from which they had died.

This fungus (*Sporotrichum*) was first cultivated artificially on agar-agar by Prof. Roland Thaxter, of New Haven, in April, 1891, and by me on the corn-meal mixture and similar substances in May of that year, such cultures being first successfully used here for the infection of healthy chinch-bugs in the following month.

The earliest field experiments with the contagion method for the chinch-bug were, however, those made by Prof. Lugger in Minnesota in October, 1888, but the agent of contagion in this case was said to be the Entomophthora of the chinch-bug instead of Sporotrichum. It is very probable that both forms were present. Certainly the Sporotrichum appeared spontaneously among living chinch-bugs sent me from Minnesota by Prof. Lugger in October, 1888.*

The credit of first testing precisely the effect of varying degrees of atmospheric moisture on the growth of Entomophthora, and of following step by step the progress of an infection introduced into the field, with careful reference to varying weather conditions, is due to Mr. F. M. Webster, of Indiana. His experiments were made with dead specimens received from Kansas in July and August, 1889. The same possible uncertainty exists as to the forms of the fungous parasites used in this work as in that of Prof. Lugger, mentioned above.†

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* Prof. Lugger informs me that both Entomophthora and Sporotrichum were unquestionably present in his specimens. [April 3, 1895.]

† Prof. Webster writes me that the chinch-bug Entomophthora (*E. aphidis*) was undoubtedly present on these insects, the determination having been made by Prof. J. C. Arthur, Botanist at Purdue University, but that it is possible that the Sporotrichum may have been present also. [April 3, 1895.]

Prof. F. H. Snow's distribution to Kansas farmers of about fifty packages of chinch-bugs in 1889 and of thirty-eight such packages in 1890, led to legislative action in Kansas, in March, 1891, of a kind to bring about a new departure in American economic entomology, inasmuch as appropriations were then made by the General Assembly of that State for the establishment and maintenance of a laboratory whose function it should be to prepare and distribute to farmers, free of expense to them, material capable of conveying the chinch-bug diseases by contagion to healthy insects in their fields. This laboratory, established at the Kansas State University at Lawrence, Kansas, has continued in operation to the present writing (1894). From it were sent out 1,400 lots of dead or infected chinch-bugs in 1891, 1,848 in 1892, and 3,803 in 1893, or over 7,000 for these three years. These lots consisted each of a few infected bugs, commonly less than a dozen, and were accompanied by directions to the recipient for their use in propagating the white muscardine, first in closed boxes and thence in the field. As it was intended that the contagion boxes thus established should be used continuously for the multiplication of the parasitic Sporotrichum, and as many farmers were frequently supplied from a single box, establishing by this means boxes of their own, the actual number of trials was doubtless much greater than 7,000.

The method of these field distributions was necessarily such that only a very small part of them could be preceded and critically followed up by expert inspection in the field, and the statement of results reported consequently rests almost wholly on the observation and judgment of the farmers to whom this contagion material was sent. Generalizing their usually uncritical and uncriticised statements, it appears from the voluminous annual reports of the Kansas laboratory that approximately 59 per cent. of the cases have been classed as successful experiments, 24 per cent. as doubtful, with a remaining 17 per cent. as unsuccessful "on the face of the returns." If we accept as decisive only reported observations of *dead chinch-bugs* in the field following upon the introduction of the contagion material, the number of such cases amounts for 1891 and 1893 (reckoned separately and afterward combined) to approximately 33 per cent. of the whole; or if, remembering the notoriously common blunder of the average observer in mistaking cast skins of chinch-bugs for dead insects, we accept only those reports of success in which mention is made of fungus-covered bugs, we find the ratio of such reports to be about 18 per cent.

There are abundant reasons, however, to lead us to discount heavily even these last ratios if we would be certain to include in our estimate only cases of proved success. In the first place, there is only occasional evidence that these farmers' observations in their own fields were checked by simultaneous and parallel observations in other fields not previously infected. Nothing seems usually to have been done, that is, to detect and eliminate cases of a general spontaneous occurrence of muscardine. There is also little or nothing in the published reports to indicate that the reporters took account of the fact that spent adults, about to die in the course of nature, are especially liable to infection, and that such cases of infection are worthless as evidence of the economic utility of the contagion method. We must further remember that chinch-bugs dying normally sometimes become covered with a *post-mortem* mold readily mistaken by the uncritical observer for the fungous parasite; and that even the freshly moulted adult has been more than once mistaken for the fungus-covered chinch-bug by experimenting farmers, misled by the white color of the insect just after it has escaped from its pupal "crust."

These considerations, together with long practical experience of the unsatisfactory character of the statements of miscellaneous observers, taken without selection, concerning difficult and unfamiliar matters of this description, lead me to attach but little value to this kind of evidence, for or against, and to look rather for the basis of a judgment on the economic bearing of this Kansas work to the descriptions of experiments by the laboratory assistants themselves.

THE WORK IN ILLINOIS IN 1891–1894.

Previous to 1891, my own experimental work on the insect diseases had been done almost wholly with bacterial forms, but in the spring of that year I began culture and infection experiments with *Sporotrichum globuliferum*, the fungus of white muscardine, and have continued now for four successive seasons to give particular attention to this species from the economic standpoint. It has not been possible, however, with the funds and assistance at my disposal, to give the continuous attention of even one person to this investigation, and the incomplete and sometimes doubtful character of many of our results is usually to be attributed to unavoidable interruptions of studies which should have been continuous. We have endeavored to investigate, so far as possible, the spontaneous prevalence of white muscardine in the field; to determine the cheapest, best, and most convenient method and apparatus for the artificial culture of the muscardine fungus and of some other fungi of similar habit; to bring into comparison inoculation experiments in the laboratory and the field with spores derived from such artificial cultures and similar experiments with those coming directly from the dead insect itself; and to test the economic value of various methods for the increase and extension of this muscardine in the field, either as a preventive measure when chinch-bugs are relatively few, or as a means of arresting their ravages when they are excessively abundant and destructive.

Spontaneous Occurrence.

Notwithstanding the prevalent drouths of 1891, 1892, and 1893, and the consequent absence of any considerable outbreak of contagious disease among chinch-bugs, as well as the failure of all our attempts at the artificial introduction of white muscardine in Illinois, a sufficient number of fungus-covered specimens were found from time to time in widely separated places, to show the presence of that disease in here and there a locality. *Sporotrichum globuliferum* seems, in fact, very commonly, if sparingly, present among insects in this latitude in a condition to give local origin to this fungous attack whenever favoring circumstances supervene.

June 6, 1891, half a dozen dead chinch-bugs covered with Sporotrichum in a fruiting condition were found lying upon the surface of the ground in a wheat field near Litchfield, Montgomery county; and in a lot of specimens obtained June 2 from this same field and kept in a breeding cage at my insectary, many bugs showed the presence of this fungus upon their dead bodies only three days thereafter.

May 23, 1892, among several hundred chinch-bugs received from near Highland, in Madison county, two were noticed densely covered with Sporotrichum; and July 20 of the same year many young bugs were found dead and dying under a dense growth of grass in a field of rye near Forreston, in Ogle county, in northern Illinois, their bodies being thickly covered with this fungus. This was apparently a local occurrence, as nothing of the kind could be found in adjoining fields; but this little outbreak continued at least for nearly a month. On a later visit, August 13, fungus-covered bugs were abundant in a narrow strip of grass separating this field of rye from corn, although none could be detected in the corn itself. The latter was swarming with seemingly healthy bugs, which could only have entered the field by passing through the three-foot belt of grass in which thousands of dead bugs remained. On this last date adult chinch-bugs covered with Sporotrichum were detected in considerable numbers in a field of barley in this same neighborhood, mostly among dense weeds and grass; and on still another farm a smaller number occurred in corn. In fact, this fungous disease seemed at this time sufficiently prevalent here to promise considerable relief from chinch-bug injury the following year. (See Eighteenth Report State Entomologist of Illinois, page X.)

August 8, 1893, two dead chinch-bugs imbedded in this same fungus growth were picked up in a field near Shattuc, Clinton county; and another similarly imbedded in a fruiting growth was found the following October in corn at Tamaroa, in Perry county.

The occurrence of this same Sporotrichum was noted also during these same years on other insects: April 4, 1892, on cocoons of *Halesidota caryæ* found under logs and other rubbish on the ground; May, 1892, on a plant bug, *Euschistus variolarius*, in a Washington county wheat field; November 5, on a caterpillar, (*Nodata gibbosa*) shaken from an oak tree near the University; and November 8, on two dead beetles (*Evarthrus colossus* and *Xylopinus saperdoides*) collected near Urbana, in Champaign county, under a fallen tree.

The identity of this fungus species was in all these cases determined by artificial cultures made from the specimens collected. The spontaneous appearance of Sporotrichum in the field was much more frequently reported in 1894 than in the preceding year, the drouth being in fact less severe and continuous, and the chinch-bug much more abundant. A general prevalence of muscardine to some small extent on chinch-bugs in the fields of southern Illinois was detected in June, and again in September and October, all trace of it having in the meantime disappeared with the advent of a long midsummer period of heat and drouth. Particulars to this effect may be found farther on in this paper in the description of experiments Nos. 53, 55, 57, 60, 63, 64, 65, 66, and 67 of the series for 1894.

Number and Nature of Experiments.

The list of recorded experiments in field and laboratory for the four years mentioned numbers two hundred and eighty-five, of which one hundred and one belong to the year 1891, eighty-six to 1892, eighteen to 1893, and eighty to 1894. The work of the first of these four years was naturally largely devoted to culture experiments and to laboratory experiments with infection methods—thirty-nine of the former and forty-one of the latter for that year. The work of 1892 consisted chiefly of variations and elaborations of that of the preceding year, and included one field experiment. Other parasitic fungi (*Botrytis tenella* and *Isaria leprosa*) were also taken up and similarly handled. In 1893 especial attention was first given to experiments for the introduction of the chinch-bug diseases in the field, and in 1894 a general programme of laboratory experiments and field distributions was entered upon, some two thousand of the latter being made during the year. The most important work of this season consisted in field experiments on a large scale, made by assistants of the office and by others personally known to me, which experiments were followed systematically throughout the season and studied in detail from month to month.

Summary of Economic Results.

The principal economic outcome of this whole investigation may be thus briefly summarized:

1. White muscardine of the chinch-bug is a contagious disease due to parasitism by the fungus species *Sporotrichum globuliferum.* It affects a large number of other insects as well, and probably never dies out entirely over any large area of the State, but is always sufficiently prevalent and common under all conditions to furnish a suitable beginning for a spontaneous spread wherever an insect species, like the chinch-bug, becomes for a time superabundant under conditions favorable to the growth and reproduction of the fungus characteristic of this disease.

2. The conditions necessary to its appearance among chinch-bugs on the epidemic scale are an abundance of the bugs themselves and a considerable amount of wet weather with not too low an average temperature.

3. Its hidden presence among bugs which, as observed in the field, seem to be wholly free from it, may often be demonstrated by shutting up such bugs for two or three days in a moist atmosphere; but, on the other hand, as this procedure often fails to develop it, it is not always and everywhere present.

4. Its characteristic fungus may be easily cultivated on certain mixtures of animal and vegetable substances, or on either of these substances alone—plain beef broth or simple agar-agar, for example. The cheapest and most satisfactory mixture thus far used is corn meal saturated with beef broth.

5. It can only be grown on these media in the absence of the germs of fermentation and decay. If these are not excluded, they take possession of the surface, and the muscardine fungus will not grow in competition with them; methods of sterile culture are therefore indispensable. The most convenient apparatus of sterile culture used by us is a circular copper pan (Pl. VIII) nine inches across and one inch deep, with straight sides, and a cover which shuts over the pan like the lid of a pill box. A less convenient but slightly safer apparatus is a Mason fruit-jar, with the metal cap altered by the insertion of a tube which may be plugged with cotton as a protection against bacteria and other fungus germs. (Pl. V., Fig. 1).

6. Propagation of this fungus to living insects is easy if the atmosphere is kept moist. We have found as yet little, if any, reason to believe that the cultivated Sporotrichum is any less active as an agent of infection than that grown on the insect body. Its spores will germinate on the surface of infected insects, sending their thread-like outgrowths through the cuticle; but soft-bodied forms, like caterpillars, are, as a rule, more easily infected than those with a hard crust.

7. The distribution of the Sporotrichum in the field will have no immediate effect if the weather is dry, but spores may live in a dry state for many months, and may thus give origin to an outbreak of muscardine, if the weather changes, long after they have been distributed.

8. The readiest and most convenient method of rapid propagation and general distribution of muscardine is to grow the fungus on corn-meal batter mixed with beef broth, by the sterilization methods of the bacteriological laboratory, and to distribute this cultivated fungus to farmers with instructions for its use. For its dissemination in their fields chinch-bugs are to be infected by exposure to the fungus in tight wooden boxes with a layer of earth in the bottom of each box. The imprisoned bugs must be supplied with food, which should be renewed as necessary, and the contents of the boxes must be kept continuously moist. As the bugs show evidence of disease, a part of them are to be scattered in the fields at intervals, their places being taken by fresh bugs put in the box. This operation is to be continued until the desired result appears. A more convenient method and one less liable to miscarriage through failure of the farmer to carry on successfully operations for the propagation of the fungus, is the distribution of the cul-

tivated spores in sufficient quantity to permit their direct application in the field. This would require, however, a very large central plant for cultivation and distribution, and is not to be recommended until the economic value of the whole method has been more satisfactorily tested.

It seems barely possible that culture methods may be so simplified by further experiment as to bring them within the resources of the intelligent and careful farmer.

9. The precise economic value of this method is not as yet, by any means, fully known. It seems to be, in Illinois, at best a means of hastening the appearance of the muscardine and of accelerating its spread among chinch-bugs under favorable weather conditions; but how much it may actually hasten either the appearance or the spread remains yet to be ascertained.

We may say, in brief, that the agricultural effect of a chinch-bug attack is to hasten and intensify the evil consequences of drouth; and that the contagious disease of that insect here treated has merely the effect to hasten and intensify the beneficial consequences of wet weather.

A considerable number of additional results of minor economic interest may be found stated under the discussions of experiments with which the account of the work for each year is introduced.

WORK OF THE YEAR 1891.

The work of the year 1891 upon the contagious diseases of insects, and especially of the chinch-bug, was limited wholly to laboratory experimentation, no field experiments of any description being made. It was in continuation of the previous work of my office, as described in my earlier reports, but was immediately suggested by a spontaneous outbreak of white muscardine in a collection of hibernating beetles (*Disonycha pennsylvanica*) kept under my observation during the spring of this year, and by an artificial culture of the fungus of white muscardine (*Sporotrichum globuliferum*) on agar-agar received from Prof. Thaxter, of Harvard University, about May 15.

The experimental work of the season consisted of cultures of Sporotrichum and of contagion or infection experiments with chinch-bugs, cabbage worms, and other insects, by the use of the spores of this same fungus as an infection material. Culture experiments were made in part by the sterilization methods of the bacteriological laboratory, and in part without sterilization, in the open air. Five of the sterile cultures were made on peptonized agar-agar, twenty-two on corn meal mixed with beef broth, and four each on sawdust, middlings, and bran, wet up with the same liquid. The open-air culture experiments were twenty in number, thirteen on various mixtures with meal, two on horse droppings, one on bread, two on boiled beef, and two on raw egg.

The contagion or infection experiments numbered forty-one, twenty-one of them with chinch-bugs, three with cabbage worms and seventeen with miscellaneous insects. In the chinch-bug work the infection material for one experiment was obtained from the hibernating beetles (Disonycha) already mentioned; that for seven others came from chinch-bugs dead with muscardine; that for one from a dead cabbage worm; and that for the remaining nine from various cultures of Sporotrichum. The infection material for the experiments with other insects was all from the cultivated fungus.

Cultures of Sporotrichum.

Sterilized Cultures.—The culture apparatus used by us was in all cases either the common test-tube with a cotton plug, or a glass fruit jar of the Mason pattern (usually of a capacity of two quarts), the metal cap of which screws on to the top of the jar with a flat rubber ring intervening. The caps were altered by closely soldering a tin tube into an opening in the top of each (see Plate V., Fig. 1), as a safeguard against accidental infection by bacteria when the spores were sown upon the medium, and also for the purpose of convenient plugging with cotton as a subsequent protection.

In charging this jar with the culture medium, the metal cap was removed and the jar was partly filled with the corn-meal batter, mixed barely thick enough to settle smoothly, and was then placed upon its side, so that the mixture collecting at the lower part of the jar might present as large a surface as possible for the growth of the fungus. This culture jar worked very satisfactorily, any secondary infection of the culture rarely interfering with the growth and complete development of the Sporotrichum.

The cover of the jar was of course removed to get access to its contents, and if it was desired to preserve the culture for some time without deterioration the jars were left open until the contents were dried out. (See Plate VI.) It was found that such dried masses of corn meal with surfaces covered with Sporotrichum growths could be readily and successfully freshened and revived after some months by simply moistening the mass.

Our test-tube cultures on agar-agar, the spores for which were derived from the tube of this fungus sent us by Prof. Thaxter, were all made in the botanical laboratory of the University of Illinois. They served merely to demonstrate the readiness and convenience with which cultures of this fungus may be made on peptonized agar, the substance most commonly used for the culture of bacteria on solid media.

A much larger number of cultures on other substances were made in my own laboratory, mostly by Mr. John Marten, one of my entomological assistants. As it was our principal object at this time merely to ascertain what medium could be used most conveniently and successfully for the multiplication of this fungus on a considerable scale, for experimental purposes, the details of our cultures were not followed out beyond the point of immediate practical utilization. For this reason scarcely any experiments were undertaken under conditions other than those present in an ordinary occupied room, and only such notes of the progress of growth, time of fruiting, etc., were made as would enable us to tell how soon after sowing spores we might expect a new growth in a condition for use as infection material.

As a general result of these experiments it appeared that the medium used made but little difference with respect to promptness of germination or the rate of subsequent growth, these being dependent, within the limits of our trials, on temperature rather than on the particular kind of nutriment provided for the growing fungus.

A mixture of raw corn meal with beef broth, to form a stiff batter, was on the whole the best substance used by us this year, and the Mason fruit-jar--the metal cap of which had been altered by the insertion of a tin tube for the reception of a cotton safety plug--was the most convenient and cheapest vessel in which to grow the fungus.

The average time elapsing between the sowing of the spores and a visible surface growth was two days, although in a few cases growth was detected on the day after infection, and in one case an interval of three days elapsed. This last, however, was a culture on sawdust wet with beef broth, in which the whole growth was very scanty and slow, and consequently inconspicuous at first.

The surface of the substance infected was substantially covered by a spread of the growth from its many scattered centers in from three days to a week, with an average of five days, and heads of young spores began to show within the tube or jar, to an ordinary observation, in from five to ten days. The spores began to ripen, as evidenced by a yellowish tint of the surface of the culture, in from one to two weeks, with an average period of nine or ten days; and they were thoroughly ripe and easily detached by jarring or shaking in eleven to twenty-one days, or after an average interval of about two weeks.

From trials made with fungus cultures that had lain some months after drying out spontaneously, it appeared that dry spores not less than five or six months old grew as promptly and as freely as if they were fresh, but the original Thaxter culture, on the other hand, was completely dead seven months after its receipt by us.

A single experiment, which has been verified by later work, showed that when the temperature of the moist culture medium approximated 100°, germination of the spores was prevented.

Three trials made with the usual culture medium acidulated with tartaric acid of three to five per cent., showed that this kind and amount of acidity was fatal to the experiment, as no growth occurred.

The infection of suitable culture substances from dead insects obtained in the field, covered with Sporotrichum, occasionally gave pure growths of this parasitic fungus, but much more frequently the growths were mixed, other fungi ultimately crowding out the Sporotrichum, if, indeed, this were permitted to start at all. It would be better, consequently, as a rule, to make the original beginning from such accidental finds, by exposing healthy insects (caterpillars by preference) to contagion from the dead insects and making the artificial cultures afterwards from these purposely infected specimens.

The following table will serve as a synopsis of the data upon which the foregoing statements concerning sterilized cultures* are based. The figures in the first column refer to the detailed description of experiments following, and those in columns four to eight represent the number of days after infection:

Table of Sterilized Cultures of Sporotrichum globuliferum, 1891.

No.	Date.		Medium.	Visible growth.	Surface covered	Spore-heads formed.	Yellowish.	Ripe.	Remarks.
15	June	11	Corn meal	—	—	5	8	11–13	....
32	"	11	" "	2	—	5	7	11–13	....
68	"	12	" "	2	—	5	11	12	....
87	"	12	" "	2	5	8	10	15	Blue mold ....
24	"	23	" "	0	0	0	0	0	5% tartaric acid......
25	"	23	" "	0	0	0	0	0	5% " " ....
26	"	23	" "	0	0	0	0	0	5% " " ....
27	"	23	" "	0	0	0	0	0	3% " " ....
91	"	30	" "	0	0	0	0	0	Blue mold............
92	"	30	" "	0	0	0	0	0	" " ....
93	July	3	" "	0	0	0	0	0	Foreign fungi ....
78	"	7	" "	2	3	—	12	14	....
45	"	7	" "	2	3	10	12	—	....
35	"	9	" "	0	0	0	0	0	90–102° Fah..........
47	"	9	" "	1	—	—	11	15	....
50	"	9	" "	1	—	—	11	15	....
31	"	10	" "	2	—	—	10	14	72° Fah..............
94	"	16	" "	2	4	8	—	—	....
56	Dec.	21	" "	1	—	9	14	21	6½ months old.........
84	"	21	" "	0	0	0	0	0	7 " " ....
95	"	21	" "	2	7	9	14	21	5 " " ....
101	"	22	" "	2	6	—	—	—	Foreign fungi.........
41	June	11	Middlings	2	7	5	9	11	....
52	"	11	"	2	—	—	6	11	Very scanty...........
72	"	12	"	2	—	—	6	12	....
89	"	12	"	0	0	0	0	0	Foreign fungi.........
53	"	11	Bran	2	5	5	6	11	....
54	"	11	"	2	—	5	8	9–11	....
77	"	12	"	2	—	6	7	13	....
88	"	12	"	0	0	0	0	0	Profuse mold..........
39	"	11	Sawdust	2	—	—	9	—	Very scanty...........
40	"	11	"	2	—	—	9	—	" " ....
71	"	12	"	3	0	8	10	—	" " ....
90	"	12	"	0	0	0	0	0	Profuse mold..........
				1–3	3–7	5–10	7–14	11–21	

Unsterilized Cultures.—In the hope of avoiding the inconvenience and uncertainty of the sterilized-culture method, attempts were made to grow the Sporotrichum in the open air on suitable media, chiefly upon corn-meal mixtures, but also upon other substances used by botanists for the culture of fungi. These experiments failing,—evidently because of bacterial invasion of the material and consequent fermentation and decay,—additional trials were made with the same media variously acidulated with tartaric acid, in the hope that this treatment would so retard bacterial development as to permit a start of the Sporotrichum. As these experiments were all absolute failures, detailed discussion of them is unnecessary.

* Agar cultures 7–10, 13, and 14 are omitted from this table, because of a lack of detailed notes of growth.

*Contagion and Infection Experiments.**

With Chinch-bugs.—Our laboratory experiments for the conveyance to chinch-bugs of the disease known as white muscardine number twenty for this year. Three of these, however, 57, 98, and 100, are to be rejected on account of an infection of the check. Chinch-bugs died with muscardine in the lots separated in the beginning as a check on the experiment, thus discrediting the results in the experimental lot. Two others, Nos. 30 and 46, may also best be omitted, since, although bugs died in the experimental lot, the conditions and management were such that no assurance can be had that they died of muscardine.

Arranging the remaining eleven in the order of promptness of the appearance of the Sporotrichum among the chinch-bugs, they stand as follows:

No. 4. A contagion experiment; spores derived from dead chinch-bugs. First insect dead with Sporotrichum in two days.

No. 29. An infection experiment; spores from an artificial culture four removes from dead insect. First appearance of Sporotrichum, three days.

No. 2. A contagion experiment; spores derived from dead beetles (*Disonycha*). First insect dead in three days; first appearance of Sporotrichum, eight days.

No. 6. Contagion experiment; spores derived from dead chinch-bugs. First bug dead with Sporotrichum in five days. In this experiment the dead chinch-bugs from which the infection was derived were enclosed with the live chinch-bugs only twenty-four hours, and were then removed.

No. 3. Contagion experiment; spores derived from dead chinch-bugs. Infection temporary. Dead bugs removed in twenty-four hours. First specimens dead in five days; first development of Sporotrichum in nine days.

No. 70. Infection experiment; spores from culture two removes from dead insect. First bug dead with Sporotrichum in seven days.

No. 99. Contagion experiment; spores from dead chinch-bugs received from Kansas. First specimens dead in seven days; first appearance of Sporotrichum in thirteen days.

No. 85. Contagion experiment; spores derived from dead chinch-bugs. Temporary infection; exposed forty-eight hours. First bug dead with Sporotrichum in nine days.

No. 59. Infection experiment; spores from culture two removes from dead insect. First chinch-bug dead with Sporotrichum in eleven days.

No. 97. Contagion experiment; spores derived from chinch-bugs received from Kansas State University. First bug dead in this lot in thirteen days; first appearance of Sporotrichum in twenty-four days.

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*For convenience, I have used the word "contagion" whenever the spores of fungi or other germs of disease were transferred to living insects immediately from other insects dead or affected with the disease in question; while the word "infection" has been reserved for cases in which these germs were derived from artificial cultures.

No. 96. Contagion experiment; spores derived from chinch-bugs received from Kansas State University. First bug dead in this lot in thirteen days; first appearance of Sporotrichum in twenty-six days.

In Nos. 11, 12, and 86—all infection experiments—and in contagion experiment No. 34, the material for which was derived from dead cabbage-worms, no visible effect resulted, the chinch-bugs exposed continuing without loss.

It is further to be noted that in No. 29 of the above series, most of the bugs treated were alive after twenty-five days; that in No. 2 all were dead but one in eighteen days; that in No. 70, out of several hundred chinch-bugs exposed only twenty-four had succumbed in eighteen days; that in No. 99 about one fourth were still alive in thirty-five days; that in No. 96 only a few were dead after the same interval, and that in No. 97 eighteen were living after seventy days had elapsed.

In scanning these reports, I am not able to discover any sensible difference of results corresponding to differences in the source of the fungus, whether derived from the body of the dead insect or from an artificial culture; neither does there seem to be any difference in the effect of cultures corresponding to the difference in the number of generations grown successively upon artificial media.

With Miscellaneous Insects.—Miscellaneous infection experiments made with cultures ranging from the first to the sixth remove from the original insect, numbered twenty in 1891. Arranging these, like the preceding series, in the order of promptness of the appearance of the Sporotrichum, they stand as follows:

No. 64. Saw-fly larvæ infected from original Thaxter culture, first remove from insect. Specimens under bell-jar. First dead in three days; external growth same day. In eight days all showed external growth but two. No loss in check after eleven days.

No. 33. An infection of fifty cabbage worms; spores from artificial culture of the fifth remove. Specimens in breeding-cage on damp sand. Three days, six dead; four days, twenty dead, and first external appearance of Sporotrichum. Seven days, all dead. Check in the meantime without loss.

No. 65. Infection of saw-fly larvæ; spores first remove from insect; specimens under bell-jar. First larva dead in four days, showing external growth of Sporotrichum. Eight days, all dead, and all but three with external fungous growth. No loss in check in eleven days.

No. 36. Infection of one hundred cabbage worms with spores from various sources, second to sixth removes. Kept outdoors on food plant. First dead in three days; internal growth of Sporotrichum detected in six days; external growth in nine days. In seven days fifty-four dead, but with much hymenopterous parasitism. Sixty-six dead in nine days, and eighty-five dead in twenty-two days. In check, several dead with hymenopterous parasites, but no Sporotrichum.

No. 58. Infection of plant-lice; spores of second remove; kept in breeding-cage on damp earth. First dead in six days, all dead in eight days, most of them covered with Sporotrichum. In check, all dead, but without fungus.

No. 48. Infection of caterpillars (Hemaris); spores of the fifth remove; kept in breeding-cage. First larva dead in six days, Sporotrichum showing externally in eight days. In nine days all dead but one. No loss in check.

No. 37. Infection of two hundred fall web-worms, spores varying from second to fifth remove. Kept in breeding-cage. First caterpillar dead in eight days; first external fungus in nine days. In thirteen days nearly all dead, and most of them with external fungous growth. No Sporotrichum in check.

No. 66. Infection of plant-lice; spores two removes from insect. In nine days all dead with Sporotrichum. None dead in check.

No. 55. Infection of four caterpillars (Hemaris); spores at three removes. Kept in breeding cage. All dead in ten days, with Sporotrichum on one. In twelve days all with external growth. Check without loss.

No. 49. Infection of miscellaneous insects with spores at five removes. Kept in breeding-cage. Grasshoppers beginning to die in four days, and in eight days nearly all dead. First external growth of Sporotrichum on the tenth day, increasing to the thirteenth and twenty-fourth.

No. 67. Infection of eight Cecropia moths with original Thaxter spores, one remove from insect. Kept in breeding-cage on damp earth. Two dead in two days; all dead in seven days; first Sporotrichum growing externally on the 11th day. Moths of check also dead in fortnight, but without Sporotrichum.

No. 51. Infection of sixty caterpillars (Datana) with spores of fifth remove. Specimens in breeding-cage. Two dead in four days; seventeen in five days; Sporotrichum growing internally. In seven days first external growth; in nine days all dead but one; and in fifteen days nearly all covered with Sporotrichum. In the check lot two died in the meantime, but without appearance of fungous disease.

No. 38. Infection of fall web-worms by enclosure in infected breeding-cage. First dead with Sporotrichum in seventeen days; no further development.

Nos. 62 and 63. Like 58, but with only a slight appearance of Sporotrichum.

The remaining five numbers gave only negative results.

No. 73. Infection of potato beetles (Doryphora) with spores of two removes. Fungus scarcely ripe.

No. 74. Infection of crickets; spores from same source as in 73.

No. 42. Infection of tomato worms (Protoparce); spores of fourth remove.

No. 5. Infection of June beetles; spores from Disonycha.

No. 69. Infection of cabbage worms; spores of second remove; kept outdoors.

From the foregoing it would again appear that there is little discernible difference in efficiency between spores of cultures derived immediately from the insect and spores of at least the fifth remove from the generation growing on an insect host. It is also evident that a variety of other insects, the soft-bodied larvæ especially, are at least as susceptible to this fungous disease as are chinch-bugs, in connection with which it has been most frequently mentioned. A fuller discussion may well be postponed until the experiments of subsequent years are brought into comparison with those of 1891. Additional particulars may be obtained by the interested student from the outline of experiments following—the purpose of which is to show the order of dependence of successive experiments—and from the detailed description of experiments containing all the essential particulars of the work for 1891.

OUTLINE OF EXPERIMENTS WITH CHINCH-BUG MUSCARDINE FUNGUS (SPOROTRICHUM GLOBULIFERUM, SPEG.), NUMBERS 1–101, APRIL 27 TO DECEMBER 22, 1891.

No. 1, April 27. Isolation experiment with chinch-bugs.

No. 2, May 11. Contagion experiment with chinch-bugs and Disonycha.

Nos. 3, 4, and 85, May 29 and June 1. Contagion experiments with chinch-bugs.

No. 5, May 11. Contagion experiment with June beetles and Disonycha.

No. 6, May 29. Contagion experiment with chinch-bugs, material from Dr. Snow.

No. 7, May 15. Agar culture of Sporotrichum from Prof. Thaxter.

Nos. 8–10, May 18 to 20. Agar cultures.

Nos. 11 and 12, June 20. Infection experiment with chinch-bugs and No. 10.

No. 13, May 20. Agar culture.

No. 14, June 4. Agar culture.

No. 15, June 9. Corn-meal culture.

Nos. 16–23, June 23 and 24. Open-air cultures on corn-meal mixtures.

Nos. 24–27, June 24. Acidulated corn-meal cultures.

No. 28, June 26. Open-air cultures on bread.

No. 29, June 29. Infection of dead chinch-bugs.

No. 30, July 6. Chinch-bug infection from Nos. 15, 32, and 54.

No. 31, July 10. Corn-meal culture.

No. 32, June 9. Corn-meal culture.

No. 33, June 29. Cabbage-worm infection.

No. 34, July 6. Chinch-bug contagion.

No. 35, July 9. Corn-meal culture.

No. 32 continued:—

No. 36, July 28. Cabbage-worm infection from Nos. 32, 41, 50, and 72.

No. 37, July 28. Fall web-worm infected from Nos. 31, 32, and 68.

No. 38, August 24. Infection experiment with fall web-worm.

Nos. 39 and 40, June 9. Sawdust cultures.

No. 41, June 9. Middlings culture.

No. 42, June 30. Infection experiment with tomato-worm.

Nos. 43 and 44, July 7. Cultures on raw egg.

No. 45, July 7. Corn-meal culture.

No. 46, July 9. Chinch-bug infection.

No. 47, July 9. Corn-meal culture.

No. 48, July 27. Infection experiment with Hemaris larva.

No. 49, August 29. Infection of grasshoppers, etc., from 47 and 50.

No. 2, (1892.)

No. 50, July 9. Corn-meal culture.

No. 51, July 27. Infection of Datana larvæ.

No. 2, (1892.)

No. 52, June 9. Middlings culture.

Nos. 53 and 54, June 9. Bran cultures.

No. 55, July 27. Infection of Hemaris larvæ.

No. 56, December 21. Corn-meal culture.

(See Nos. 26 and 27, 1892.)

No. 57, June 5. Chinch-bug infection.

No. 58, June 6. Plant-louse infected.

No. 59, June 8. Chinch-bug infection.

Nos. 60 and 61, June 16. Open-air culture on boiled beef.

Nos. 62 and 63, June 16 and 18. Plant-louse infections.

Nos. 64 and 65, May 22. Infection of miscellaneous insects.

No. 66, May 25. Infection of plant-lice.

No. 67, June 1. Infection of Cecropia moths.

No. 68, June 12. Corn-meal culture.

No. 69, July 8, Cabbage-worm infection from 68 and 77.

No. 70, July 13. Chinch-bug infection from 68 and 72.

No. 71, June 12. Sawdust culture.

No. 72, June 12. Middlings culture.

No. 73, June 19. Infection of potato beetles.

No. 74, June 19. Infection of crickets.

Nos. 75 and 76, July 10. Cultures on corn-meal and egg.

No. 77, June 12. Bran culture.

No. 7, Continued:—

No. 78, July 7. Corn-meal culture.

No. 79, June 15. Corn-meal culture.

Nos. 80 and 81, June 16. Corn-meal cultures in open air.

Nos. 82 and 83, June 17. Corn-meal cultures in open air.

No. 84, Dec. 21. Corn-meal culture.

No. 86, June 8. Chinch-bug infection from dead chinch-bugs.

No. 87, June 12. Corn meal culture from dead chinch-bugs.

No. 88, June 12. Culture on bran from dead chinch-bugs.

No. 89, June 12. Culture on middlings from dead chinch-bugs.

No. 90, June 12. Culture on sawdust from dead chinch-bugs.

No. 91, June 30. Culture on corn-meal from dead chinch-bugs.

No. 92, June 30. Corn-meal culture from dead chinch-bugs.

No. 93, July 3. Corn-meal culture from dead beetles, etc.

No. 94, July 16. Corn-meal culture from dead thistle caterpillars.

No. 95, Dec. 21. Corn-meal culture.

No. 96, July 21. Chinch-bug contagion experiment from dead chinch-bugs.

No. 97, July 21. Chinch-bug contagion experiment from dead chinch-bugs (Empusa).

No. 98, Aug. 7. Chinch-bug contagion experiment from dead chinch-bugs (Empusa).

No. 99, July 21. Chinch-bug contagion experiment from dead chinch-bugs (Sporotrichum).

No. 100, Aug. 7. Chinch-bug contagion experiment.

No. 101, Dec. 22. Corn-meal culture from dead grasshoppers.

CLASSIFIED LIST OF EXPERIMENTS, 1891—NOS. 1-101.

Sterilized Cultures on Agar-agar.

No. 7, May 15. Original Sporotrichum culture from Prof. Thaxter.

Nos. 8, 9, 10, and 13, May 18 to 20. Cultures from No. 7.

No. 14, June 4. Culture from No. 13.

Sterilized Cultures on Various Media.

Corn-Meal Mixtures:—

Nos. 15 and 32, June 9. From No. 14.

Nos. 24-27, June 23. On acidulated media.

No. 31, July 10. From No. 15. Constant medium temperature.

No. 35, July 9. From No. 32. Constant high temperature.

Nos. 45, 47, and 50, July 7 to 9. From No. 41.

No. 56, Dec. 21. From No. 14.

No. 68, June 12. From No. 7.

No. 78, July 7. From No. 77.

No. 84, Dec. 21. From No. 7.
No 87, June 12 From dead chinch-bugs.
Nos. 91 and 92, June 30. From dead chinch-bugs.
No. 93, July 3. From dead beetles, etc.
No. 94, July 16. From dead thistle caterpillars.
No. 95, Dec. 21. From No. 94.
No. 101, Dec. 22. From dead grasshoppers.

Miscellaneous Media:—

Nos. 39 and 40, June 9. Cultures on sawdust from No. 14.
Nos. 41 and 52, June 9. Cultures on middlings from No. 14.
Nos. 53 and 54, June 9. Cultures on bran from No. 14.
No. 71, June 12. Culture on sawdust from No. 7.
No: 72, June 12. Culture on middlings from No. 7.
No. 77, June 12. Bran culture from No. 7.
Nos. 88 to 90, June 12. Cultures on bran, middlings, and sawdust. Spores from dead chinch-bugs.

Open Air Cultures:—

Nos. 16 and 17, June 23. On acidulated corn meal mixtures; spores from No. 15.
Nos. 18 and 19, June 23. On horse droppings; spores from No. 15.
Nos. 20 to 27, June 24. On acidulated corn-meal mixtures; spores from No. 15.
No. 28, June 26. On bread; spores from No. 15.
Nos. 43 and 44, July 7. On raw egg; spores from No. 41.
Nos. 60 and 61, June 16. On boiled beef; spores from No. 13.
Nos. 75 and 76, July 10. On cornmeal and white of egg; spores from No. 72.
No. 79, June 15. On cornmeal; spores from No. 7.
Nos. 80 to 83, June 16 and 17. On cornmeal; spores from No. 7.

Experiments with Chinch-bugs.

Contagion Experiments:—

No. 1, April 27. Isolation experiment.
No. 2, May 11. Contagion from *Disonycha pennsylvanica.*
No. 3, May 29. Contagion from dead chinch-bugs.
No. 4, June 1. Contagion from dead chinch-bugs.
No. 6, May 29. Contagion from dead chinch-bugs.
No. 34, July 6. Contagion from dead cabbage worms (No. 33).
No. 85, June 1. Contagion from dead chinch-bugs (No. 2).
Nos. 96 and 99, July 21. Contagion from dead chinch-bugs.
Nos. 97 and 98, July 21 and August 7. Contagion from dead chinch-bugs. (Empusa.)
No. 100, August 7. Contagion from dead chinch bugs (No. 99).

Infection Experiments:—

Nos. 11 and 12, June 20. Infection from agar culture No. 10.
No. 29, June 29. Infection from corn-meal culture No. 15.
No. 30, July 6. Infection from various cultures (Nos. 15, 32 and 54).
No. 46, July 9. Infection from middlings culture No. 41.
Nos. 57 and 59, June 5 and 8. Infection from agar culture No. 13.
No. 70, July 13. Infection from corn meal culture No. 68 and middlings culture No. 72.
No. 86, June 8. Infection derived from dead chinch-bugs.

Infection Experiments with Cabbage Worms:—

No. 33, June 29. Infection from corn-meal culture No. 32.
No. 36, July 28. Infection from various cultures on corn-meal and middlings (Nos. 32, 41, 50, and 72).
No. 69, July 8. Infection from corn-meal and bran cultures (Nos. 63 and 77).

Miscellaneous Infection Experiments:—

No. 5, May 11. With June beetles.
No. 37, July 28. With fall web-worms.
No. 38, August 24. With fall web-worms.
No. 42, June 30. With tomato worm.
Nos. 48 and 55, July 7 and 27. With Hemaris larvæ.
No. 49, August 29. With grasshoppers, etc.
No. 51, July 27. With Datana larvæ.
No. 66, May 25. With plant-lice.
No. 58, June 6. With the grain aphis.
Nos. 62 and 63, July 16 and 18. With plant-lice.
Nos. 64 and 65, May 22. With miscellaneous insects.
No. 67, June 1. With Cecropia moths.
No. 73, June 19. With potato beetles.
No. 74, June 19. With crickets.

DETAILED DESCRIPTION OF EXPERIMENTS.

No. 1. April 27, 1891. A lot of chinch-bugs collected (April 8 to 11) at Carlyle, Marissa, and other places in Southwestern Illinois, isolated in a bottle with green wheat for food for the purpose of ascertaining whether fungous disease was present among them. May 4, no external appearance of disease. Three bugs examined microscopically by crushing and dissection. No internal evidence of fungus.

No. 2. May 11. Contagion experiment with chinch-bugs confined with specimens of *Disonycha pennsylvanica* dead with the Sporotrichum disease.* About fifty chinch-bugs placed on earth

* See Seventeenth Report, State Entomologist of Illinois, p. 82.

under a bell-jar with green wheat and with several of the above beetles covered with fungus. May 14 first bug was dead; May 16 another; and May 19 two more had died, covered with Sporotrichum May 20, at 8 o'clock a. m., another chinch-bug was removed in the same condition. This insect had certainly been alive at 2:15 p. m., of the preceding day. May 22, two more fungus-covered-bugs removed, and May 23 an additional one. The propagation of the disease was rapid from this time to the 29th, when all the chinch-bugs of the lot but one were dead and covered with Sporotrichum. Check lot without loss.

No. 3. May 29. Contagion experiment with fresh chinch-bugs exposed to specimens dead with muscardine from No. 2. Thirty chinch-bugs collected at Litchfield, Illinois, were placed in a common breeding-cage with wheat plants and two dead bugs from No. 2 which were well covered with Sporotrichum. Twenty-four hours afterwards these two dead bugs were removed. June 3 one chinch-bug was dead; on the 7th two more had died and presented a visible growth of the fungus; June 10 two more of this lot were taken from the breeding-cage with muscardine fungus well developed upon their surfaces. A check lot of an equal number similarly placed had not suffered at all. The bugs remaining in both these lots were now used in another experiment.

No. 4. June 1. A duplicate of No. 3, except that four dead bugs were placed with the living ones and were not subsequently removed. On the 3d of June one bug was dead and covered with fungus; on the 4th one more; and on the 7th two. The insects remaining were used for another purpose June 10.

No. 5. May 11. An infection experiment performed on June beetles (Lachnosterna) with spores from dead specimens of *Disonycha pennsylvanica*—the same beetles used in No. 2. Several dead and two live June beetles were dusted with the spores and placed upon damp earth in a flower pot, which was then covered with glass. May 29 no growth of muscardine fungus; beetles dead and badly decayed, eaten in part by maggots of the genus Phora—as determined by breeding.

No. 6. May 29. A contagion experiment with chinch-bugs exposed to specimens dead with the white fungus received May 12 from Dr. Snow of the University of Kansas. Thirty live chinch-bugs collected at Litchfield, Illinois, were put in a breeding-cage and supplied with wheat plants for food. Eight dead bugs from Dr. Snow were crushed and put in this cage, where they were left twenty-four hours.

June 3 one bug was dead and covered with fungus; on the 7th three more had died, two with and one without the fungous growth; and two others dead with the disease were removed the 10th.

A check lot of an equal number was similarly placed. June 3 one bug was dead in this check; and on the 5th one more had died, but neither had any visible fungus on their bodies. June 10 all the others in both lots were alive, and the insects remaining were used for other purposes.

No. 7. May 15. A tube of agar containing a profuse growth of *Sporotrichum globuliferum*, fruiting abundantly, received from Dr. Roland Thaxter, of New Haven, Connecticut. The spores used in this culture were derived originally from caterpillars of a noctuid moth (*Copipanolis vernalis*), which Dr. Thaxter was rearing in a breeding-cage. The culture was begun early in April, and was fully matured when received.

Nos. 8, 9, and 10. May 18–20. Successive culture experiments, in test-tubes, on agar inoculated with spores from No. 7, all of which produced an abundant growth of *Sporotrichum*. These cultures were made as an accommodation in the botanical laboratory of the University of Illinois, and detailed notes were not made.

Nos. 11 and 12. June 20. Infection experiments on young chinch-bugs treated with spores from No. 10. In the first (No. 11) several dozen young chinch-bugs, collected at Carlyle and Marissa, were placed in water, the surface of which had been previously dusted with spores of the white fungus from No. 10. They were left for a few minutes, then removed and placed on growing corn under a gauze-covered glass cylinder breeding-cage.* In the second (No. 12) an equal number of young bugs from the same source were placed in a dry bottle into which spores from No. 10 had been introduced, and left for a short time, after which they were enclosed in a breeding-cage similar to that used in No. 11. June 22, no fungus in either cage; bugs in good condition. June 27, no growth. June 30, no fungus development. Experiments discontinued. Check lot of an equal number of bugs kept under similar conditions also remained without loss.

No 13. May 20. Culture experiment precisely similar to Nos. 8, 9, and 10, and made in the University botanical laboratory. A tube of agar treated with spores from No. 7 produced a profuse growth of the white fungus.

No. 14. June 4. A duplicate of No. 13, except that the spores used for inoculating the agar medium came from No. 13. Similar results. Good fungous growth reported, but without details.

No. 15. June 9. Test-tube culture experiment, the nutrient material being beef broth prepared as for the culture of bacteria, and used to saturate freshly heated corn meal to form a stiff batter. June 11, 8 a. m., medium sterilized for half an hour at 100° to 108° Cent. and treated with spores of muscardine from No. 14. Kept at ordinary temperature of the room. June 13, 8 a. m., fungous growth commenced; still more prominent on the 14th and 15th; spreading freely on the 16th, and filling all the small crevices on the surface of the medium; spores beginning

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* This breeding-cage was a cylinder of glass set in earth at the bottom and covered with gauze at the top, allowing free ventilation and evaporation.

to form. June 17, the mycelial growth covering the entire surface. Heads of spores give it a distinctly granular appearance; medium drying out; 18th the same; 19th fungus slightly tinged with yellow—a sign of ripening of the spores June 20, medium dry enough to separate from tube, and fungus growing on under side; spores forming in such places. June 22, spores can be detached by vigorous shaking; June 24, easily detached and ripe; surface brownish.

The eight following (Nos. 16–23) are successive attempts made at the artificial culture of Sporotrichum in the open air upon various media, without resort to the sterilization methods of bacterial culture as given above. All were unsuccessful.

Nos. 16 and 17. June 23. Culture experiments, the nutrient material being corn meal soaked with an extract of the excrement of horses acidulated with tartaric acid, and inoculated with fungus spores from No. 15. Two quarts of fresh horse excrement stirred in two quarts of soft water, divided into two equal parts and cooked in separate water baths four hours; filtered twice through cheese cloth; one (No. 16) acidulated with one half of one per cent. of tartaric acid, the other (No. 17) with a quarter of one per cent., and mixed with corn meal. Placed in glass dishes, treated with spores of Sporotrichum from No. 15, and covered with glass. June 25, covered with molds. June 27, same condition; results negative.

Nos. 18 and 19. June 23. Culture experiments on solid horse excrement, boiled and filtered as in experiments 16 and 17, placed in tin pans, inoculated with fungus spores from No. 15, and covered with common window-glass. The two experiments were prepared alike, except that No. 19 was slightly acidulated, while No. 18 contained no acid. June 26 both were covered with mold. No Sporotrichum seen. June 27, same as yesterday. July 6, mold abundant. July 11, full of other fungi; no white fungus.

Nos. 20 and 21. June 24. Cultures on corn-meal saturated with beef broth, variously acidulated, inoculated with spores from experiment 15. Corn meal stirred in the beef broth until a thick batter was made, placed in tumblers, infected with spores from No. 15, and covered with glass. June 25, no growth of Sporotrichum. Experiment continued until the 27th with no change.

Nos. 22 and 23. June 24. Cultures on corn meal saturated with extract of horse excrement acidulated with five per cent. and three per cent. solutions of tartaric acid respectively, and infected with spores from No. 15. Culture material placed in glass tumblers and covered with glass. Experiment continued until June 27 with no growth of Sporotrichum.

The four following (Nos. 24–27) are unsuccessful test-tube cultures on corn-meal saturated with extract of horse excrement, variously acidulated, sterilized, and infected with fungus spores from experiments 15 and 77.

Nos. 24 and 25. June 24. Media prepared as in experiments 16 and 17, except that the extract was boiled a second time for half an hour, filtered through filter paper, and sterilized for half an hour at a temperature varying from 100° to 104° Cent. It was then acidulated with five per cent. of tartaric acid, mixed with corn-meal to form a stiff batter, placed in test-tubes and sterilized again for a half hour at 100° Cent. June 25, 11:45 a. m., fungus spores from No. 15 introduced with a sterilized platinum wire. July 5, no growth in either tube. A second infection of fungus spores from No. 15 introduced into No. 25. July 11, no growth.

Nos. 26 and 27, June 24. Like experiments 24 and 25, except that the fluid was acidulated with three per cent. of tartaric acid. Examined daily but no fungous growth seen. July 6, a *second* lot of spores was introduced from No. 77, a sterilized culture on bran saturated with beef broth and infected with spores from No. 7. July 8, no fungous growth. July 11, no growth; experiments discontinued.

No. 28, June 26. Culture on bread saturated with an extract of horse excrement, similar to experiments 16–23, in that the medium was not sterilized. Bread placed in a tin pan, soaked with the fluid, and infected with fungus spores from No. 15. June 30, a small patch of fungus, resembling Sporotrichum, growing on the crust. July 1, fungus of yesterday growing slowly. A second fungus, unlike the first, present on the bread. July 2, both fungi were growing freely. July 3, growth still more prominent. July 5, both fungi carefully compared with *Sporotrichum globuliferum*, and found to be very different. July 11, no Sporotrichum seen.

No. 29, June 29. Infection experiment with dead chinch-bug larvæ and pupæ from Blue Mound, Ill., treated with spores of the white muscardine from No, 15, and placed in a dry tumbler which was then covered with glass. July 2, a very slight mycelial growth on one or two bugs. July 3, growth a little more prominent. July 5, a feeble growth on a few more insects. July 24, no certain growth of Sporotrichum found on any of the dead bugs.

No. 30 July 6. Infection experiment with live chinch bugs, consisting of larvæ and pupæ, from Mr. A. H. Moule of Greenville in Bond county. Bugs placed in fruit-jars with corn leaves for food, and infected with spores of the white fungus from Nos. 15, 32, and 54. July 8, no fungus seen. Imagos more numerous. July 12, no fungous growth. Fresh food introduced. July 18, many bugs dead but no traces of Sporotrichum. Fresh food supplied. July 22, all dead, and no traces of the white fungus present.

No. 31. July 10. Test-tube culture on corn meal and beef broth prepared as in No. 78, sterilized at a temperature varying from 100° to 106° Cent., and infected with spores in the usual way. The tube was then placed in wet sand at a temperature of 22° Cent. July 11, no fungous growth. Temperature of sand 22° Cent. July 12, growing nicely. July 15, growth on the increase. July 20, yellowish tinge; surface granular. July 24, spores ripe, and easily detached.

Spores from this culture were used also to infect cultures Nos. 1 and 26, Jan. 5 and March 12, (1 92).

No. 32. June 9. Test tube culture on corn meal and beef broth prepared and sterilized as in No. 15. June 11, spores from experiment 14 introduced by means of a sterilized platinum wire. June 13, 8 a. m., mycelial threads of the white fungus visible. Growing freely on the 14th; and still more so on the 15th. June 16, surface of medium dry and cracked; fungus spreading and extending into crevices; heads of spores visible. June 17, little change; 18th, growth covering the entire surface of medium; slightly tinged with yellow. Two days later the growth had extended well under the medium where this was dry and separated from the sides of the tube. June 21, fresh growth in bottom of tube. Spores easily detached by jarring on the 22d, and readily loosened by shaking on the 24th. Spores ripe.

No. 33. June 29. Infection experiment upon fifty cabbage worms (*Pieris rapæ*) treated with spores from the preceding experiment (No. 32). Fifty cabbage worms were well dusted with fungus spores from No. 32, and placed in a common breeding-cage on damp sand, where they were supplied from day to day with fresh cabbage leaves for food. July 2, six worms were dead on the sand; and fourteen more had died on the following day. One showed an external fungous growth; and a microscopical examination of some of the others showed that the body cavities were filled with mycelial threads. Dead worms placed on damp sand under a bell glass. Six more dead on the 4th; one covered with fungus. Some of those placed on sand the 3d, covered with Sporotrichum. July 5, all the worms dead except two, and these died the following day, the greater part having an external growth of the white fungus. July 6, fifteen of the worms used for infecting No. 35; other specimens preserved.

A check consisting of a like number of worms, kept under precisely similar conditions, was started the same day (June 29), and supplied with fresh food. It remained without loss; the worms matured and pupated, and butterflies emerged July 13.

No. 34. July 6. Contagion experiment upon a lot of chinch-bugs exposed to cabbage worms covered with a growth of Sporotrichum (which had not yet reached the fruiting stage) taken from the preceding experiment (No. 33). A large number of live larvæ, pupæ, and imagos of the chinch-bug, together with a number of dead bugs, were placed on growing corn and wheat under a bell-jar, together with fifteen cabbage worms dead with the white fungus from No. 33. July 11, no traces of fungous growth on the bugs; still no growth on the 15th; and no fungous developement on bugs the 24th. Experiment discontinued.

No. 35. July 9. Culture on corn-meal and beef broth prepared as in No. 78, and infected with spores from No. 32. Meal and broth made into a thick batter, placed in a test-tube, sterilized for half an hour at a temperature of 100° to 106° Cent. and treated with fungus spores. The tube was then placed in an oven at a temperature of $38\frac{1}{2}°$ Cent. July 10, no growth; temperature 39°. July 11, no growth; temperature $37\frac{1}{2}°$. July 15, no traces of the white fungus seen. Failure of growth due probably to high temperature maintained.

No. 36. July 28. Infection experiment on 100 cabbage worms (*P. rapæ*) with spores of the white muscardine from Nos. 32, 41, 50, and 73. The caterpillars were placed after infection upon a growing cabbage outdoors, and this was afterwards covered with mosquito netting. July 30, no traces of fungus seen. Worms climbing up sides of cage preparatory to pupation. Parasitic Hymenoptera attacking them freely. July 31, one dead worm removed and placed on damp sand for further development. August 3, several larvæ dead on the side of the cage and one on the ground. The latter was examined and its body cavity was found to contain traces of the mycelium of muscardine. August 4, twenty-six pupæ, seven larvæ that had partly cast the last larval skin, and twenty other larvæ of this lot, all dead, were placed on damp sand in the insectary. Cocoons of hymenopterous parasites were very abundant under the netting and it is quite likely that a large part of the worms were killed by insect parasitism. One dead worm examined contained traces of Sporotrichum in the body cavity. August 5, a number of hymenopterous parasites have emerged from pupæ on sand in the insectary. August 6, two larvæ and one pupa show an external growth of Sporotrichum and more parasitic Hymenoptera have emerged. Seven more dead larvæ and five pupæ placed on sand. August 7, two more dead larvæ placed on sand; parasites still emerging. August 10, the larva placed on damp sand July 31 now bears a profuse growth of fruiting Sporotrichum. Twenty-two other larvæ on sand show an external mycelial growth. Eight more dead larvæ and eight pupæ removed from cage and placed on sand. August 11, eleven larvæ and two pupæ imbedded in the white fungus removed and placed in vial for future use. More hymenopterous parasites have emerged. Nothing of importance recorded from August 13 to 16. On the 17th six larvæ and nine pupæ covered with Sporotrichum were removed from the sand and placed in a vial. August 19, rain last night and to-day. One larva lying on the ground dead with the fungus taken from the outdoor cage. August 22, two more larvæ and three pupæ show slight tufts of Sporotrichum on their bodies. Experiment closed.

One hundred cabbage worms were placed in an outdoor cage similar to the foregoing July 9, and kept as a check. August 4, larvæ all right except for hymenopterous parasites. August 13, two pupæ dead with *bacterial* disease, others in good condition except for parasites. The cage remained in good condition and at no time were any traces of Sporotrichum found in it. For similar experiment see No. 69.

No. 37. July 28. Infection experiment upon fall web-worms (*Hyphantria textor*) infected with fungus spores from Nos. 31, 32, and 68. About two hundred web-worms were taken from their nest, dusted with spores of white fungus and placed in a breeding-cage with apple leaves for food. August 1 several small parasitic insects had formed cocoons within the cage. August 5, several worms dead. They become rigid, somewhat shrunken, lighter in color, and fall to the earth or rest on the leaves. No traces of the white muscardine in their body cavities. August 6, three dead larvæ in the bottom of the cage show an external growth of Sporotrichum. The live worms rather sluggish. August 10, about thirty larvæ dead with the white fungus removed and placed in bottle. Nearly all the worms are dead. August 11, a hymenopterous parasite has emerged. August 13, fourteen worms with Sporotrichum removed and placed in bottle. August 22, a profuse growth of the white fungus on all the remaining larvæ. Parasites dead and imbedded in the same fungus.

A check to this experiment, of an equal number of fall web-worms, placed in a cage July 28 and kept under precisely similar conditions, except as to infection, remained without loss from fungous disease, the larvæ pupating in due season and remaining in good condition.

No. 38. August 24. Infection experiment upon fall web-worms from wild cherry, placed in cage used for experiment No. 37. No Sporotrichum spores were introduced artificially, and the larvæ were subject to infection only from germs left by the former occupants of the cage. September 10, one larva dead and covered with Sporotrichum. Several hymenopterous parasites have emerged. September 14, other larvæ dead, but no fungus visible on their bodies; still others dead on the 17th; no more fungus. Experiment closed.

Nos. 39 and 40. June 9. Cultures on sawdust saturated with beef broth and infected with fungus spores from culture No. 14. Beef broth prepared as in No. 78; sawdust heated almost to scorching; broth and sawdust mixed to a pasty consistency, put in test-tubes, and sterilized for half an hour in an oven at a temperature varying from 100° to 108° Cent. Treated with spores June 11. July 13, 8:10 a. m., spores have begun to grow. Growth more prominent on the 14th and 15th, and spreading freely the 16th. June 17, air spaces in the medium filled in the lower part of the tubes. Less than half the surface covered with the fungus. Very slight change by the 18th and 19th. June 20, fungus yellowish and highly granular. June 22, spores not easily detached; nearly the same condition on the 24th. Successful cultures, but of relatively slow and scanty growth.

No. 41. June 9. Culture experiment identical with Nos. 39 and 40, begun at the same time, varying only in the culture medium used, which was a batter of middlings mixed with beef broth. The spores used (June 11) were from culture 14. Growth had started on the 13th, was increasing freely by the 14th, and was spreading noticeably on the 15th. Spores were forming by the 17th, and by the 18th most of the surface was covered. Tinged with yellow on the 20th and spores ripe on the 22d. Easily detached by shaking.

No. 42. June 30. Infection experiment from tomato worms (*Protoparce celeus*), treated with spores of Sporotrichum from culture No. 41. Two tomato worms were infected by rubbing the fungus spores over the spiracles with a piece of cotton, and were then placed in a breeding-cage and supplied with food. No results July 3, but the worms entered the earth to pupate the following day. One adult emerged July 31 and was preserved, and the other came out August 6. No fungus seen.

One worm was placed in a cage under similar conditions the same date (June 30) and kept as a check. The larva pupated July 4 and the adult emerged August 5. No Sporotrichum.

Nos. 43 and 44. July 7. Culture experiments with a raw egg, the white being used in No. 43 and the yolk in No. 44. Placed separately in shallow dishes, treated with spores from culture 41 and covered with glass. No growth; result negative.

No. 45. July 7. A fruit-jar culture on corn-meal batter made with beef broth, the spores for which were taken from No. 41. The beef broth used in this experiment was made by cooking one pound of beef in a quart of water for three hours, after which the liquid was poured off, and used without further treatment. The jar was partly filled with corn-meal batter, and treated with fungus spores July 8, introduced through the cap, altered to facilitate sterile culture (see Plate V, Fig. 1). July 10, growth beginning; July 11, meal covered with a fine mycelial growth, which increased and spread daily. July 20, spore clusters of Sporotrichum showing quite distinctly. July 22, spores quite yellowish and loosened by jarring. July 24, fungus as before.

No. 46. July 9. Infection experiment upon live chinch-bugs treated with Sporotrichum spores from culture No. 41. About three hundred adult bugs of the second generation placed on growing wheat, dusted freely with spores and covered with cheese cloth. Observed until July 23, at which time the bugs were all dead, but without evident signs of Sporotrichum infection.

No. 47. July 9. Test-tube culture on corn meal saturated with beef broth; sterilized at a temperature varying from 100° to 106° Cent. for half an hour, and infected with spores from culture 41. The tube was then heated to 60° Cent. for five minutes, allowed to cool, and kept at temperature of the air. A slight growth of the white fungus was noticed July 10; the growth slightly increased the 11th; still more abundant the 15th; spore clusters visible the 20th and slightly tinged with yellow. Spores not easily detached by jarring, but seemingly ripe on the 24th.

No. 48. July 27. Infection experiment upon Hemaris larvæ inoculated with spores fron No. 47. Eight larvæ, ranging from a few days' old to nearly full grown, placed in a glass dish, dusted with Sporotrichum spores, and enclosed in a breeding-cage with bush honeysuckle leaves for food. One larva dead on August 2, and several more on the 3d. The dead larva were rigid and remained in natural attitudes on twigs of plant. August

4, Sporotrichum appearing externally on the dead larva first noticed. Mycelial threads of the white muscardine found in body cavity of the others. August 5, another larva covered with the fungus, and the following day all except one showed an external growth of Sporotrichum August 10, spores were ripe on three larvæ, the growth maturing slowly on the others. Specimens of the same lot, kept in similar conditions as a check, had in the meantime continued without loss, and pupated in good condition.

No. 49. August 29. Infection experiment upon miscellaneous insects, principally grasshoppers, taken by sweeping grass. The insects were dusted with spores from experiments 47 and 50, and placed in a breeding-cage with young corn plants for food. September 1, several grasshoppers dead but no signs of the white fungus visible. Nearly all the insects had died by the 5th; on the 7th, a grasshopper with an external growth of Sporotrichum was removed, and still others on the 10th and 21st. Specimens preserved.

No. 50. July 9. Culture on corn meal and beef broth, infected with spores from culture No. 41. Broth prepared as in No. 78. Corn meal and broth mixed so as to form a thick batter, placed in a test-tube, sterilized for half an hour at a temperature varying from 100° to 106° Cent. and treated with spores. July 10, 3 p. m., a slight fungous growth apparent. July 11, growing freely. July 15, fungus spreading. July 20, yellowish tinge and granular appearance on surface. July 24, spores apparently ripe but not easily detached.

No. 51. July 27. Infection experiment upon Datana larvæ and fungus spores from the preceding culture, No. 50. About sixty half-grown Datana larvæ collected from apple-trees, treated with spores, placed in a well-ventilated breeding cage, and supplied with apple leaves for food. July 31, two larvæ dead on earth in bottom of cage. August 1, fifteen more on earth either dead or dying. Mycelial threads abundant in body cavity of all those examined. Others dead August 2, and those examined showed a greater abundance of mycelial threads in the body cavity, and in a more advanced stage of development than those examined the preceding day. A few of the dead larvæ remained attached to the top of the cage for some time. August 3, most of the larvæ dead and about half of them hanging by their prolegs to the sides of the cage or to twigs, Mycelial growth conspicuous in body cavity. Some of the larvæ first dead show an external growth of Sporotrichum. August 5, all the larvæ dead except one. The white fungus visible on about a dozen dead bodies. August 6 and 7, more larvæ with an external fungous growth. August 11, more than thirty larvæ imbedded in Sporotrichum removed and placed in bottle. Several dead larvæ covered with this same fungus left in the cage.*

* June 28, (1892), several larvæ of *Vanessa antiopa* were placed in this cage, subject to infection from the fungus-covered Datana larvæ left over from the preceding year. The experiment was successful and the white fungus readily attacked the Vanessa larvæ, some of which were completely enveloped in the fungus.

July 27, an equal number of Datana larvæ were placed in a breeding-cage under similar conditions and kept as a check. One had died on the 31st, but contained no trace of the white fungus either externally or internally. August 3, one more dead, but no fungus. August 5, remaining larvæ all right. August 7, larvæ almost full grown and in good condition. August 11, larvæ all right, and some had entered ground to pupate. Sporotrichum did not appear at any time in this check.

No. 52. June 9. Culture experiment precisely similar to No. 41. The medium consisted of a batter of middlings mixed with beef broth, and was infected with spores, June 11, from culture No. 14. There was a slight growth of Sporotrichum on the surface of the medium by the 13th, which had increased but little by the following day. On the 15th, it was confined to two small patches. By the 16th, the medium had shrunken from the tube and was quite dry on the surface. Fungous growth poor. A slight yellowish tint appeared the 17th; surface a little more granular on the 22d; on the 24th, no change.

Nos. 53 and 54. June 9. Culture experiments identical with Nos. 39 and 40, except that the medium used was a batter of bran mixed with beef broth. The spores used for infection (June 11) came from culture No. 14. Growth had started in both tubes by the morning of the 13th, and increased steadily, spreading over the surface of the medium. June 16, fungus penetrating the air spaces throughout the greater part of the mass. Spores forming. June 17, surface granular,* with a yellowish tinge, which became more marked from day to day; otherwise no perceptible change up to June 20, when spores could with difficulty be shaken off by heavy jarring. Spores ripe and easily detached June 22 to 24.

No. 55. July 27. Infection experiment upon Hemaris larvæ, precisely similar to No. 48, except that the spores used for infection were derived from No. 14. Four larvæ about two thirds grown were thoroughly treated with spores and placed in a breeding-cage with food plant. August 1, several larvæ formed cocoons. August 6, larvæ dead in their cocoons, and one shows the presence of Sporotrichum. August 8, external fungous growth visible on all the larvæ, and spores were forming on one two days later.

A check of a similar number kept under precisely the same conditions remained without loss and pupated in good condition.

No. 56. December 21. Culture experiment identical with No. 50, except that the fungus spores used came from No. 14. The corn-meal batter was placed in a test-tube and infected with spores from culture 14. A very slight fungous growth appeared December 22, which grew slowly and spread over the surface of the medium by December 30. Spores were now forming on the older part of the culture. January 4 (1892), fungus fruiting, surface with a yellowish tinge. Spores detached by vigorous jarring. January 11, growth covering the entire surface of medium; spores ripe and easily detached.

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* The granules of these notes are the heads of spores.

No. 57. June 5. Infection experiment upon chinch-bugs obtained from Litchfield, in Montgomery county, infected by means of spores from an agar culture (No. 13) of Sporotrichum. Thirty bugs were treated and placed on growing corn under a bell glass. June 7 two of the insects were dead and covered with Sporotrichum, as well as one in the check; and two days later others had died in both lots. By the 11th, nine of the thirty had perished with the fungus in the experimental lot and six in the check.

It is evident that these bugs were diseased when collected, or else that the check had become infected from the neighboring experiments.

No. 58. June 6, Infection experiment upon grain plant-lice (*Siphonophora avenæ*) collected from wheat heads, and treated with Sporotrichum spores from agar culture No. 13. The spores were dusted upon the surface of rain water, and into this the wheat heads were dipped, with the plant-lice on them. The wheat was then placed on damp earth in a glass cylinder breeding-cage. Six days later, the wheat was much shriveled and slightly covered with mould. A few dead aphids, but no traces of Sporotrichum seen. June 14, all the aphids dead, and the greater part of them covered with the white fungus. Specimens preserved.

An equal number of grain plant lice were separated and kept under similar conditions as a check upon this experiment. These were all dead by June 14, but there were no traces of the white muscardine among them, and none developed later.

Experiments 62 and 63 are identical with 58; but had a less marked result, only a single plant louse being found dead with an appearance of fungus disease.

No. 59. June 8. Infection expériment upon young chinch-bugs collected at Carlyle, dusted with spores from agar culture No. 13, and placed on growing corn in breeding-cage. The insects remained in good condition until June 19, at which time one was dead and covered with the white fungus. June 20, several other young bugs from the same source as the above were treated with spores or Sporotrichum from dead chinch-bugs imbedded in this same fungus collected at Litchfield, June 2, and placed in this cage. One young bug dead with this fungous disease was removed June 29; and one more was taken out July 3; and still others were dead July 5, and covered with the fungous growth.

The check, in the meantime, remained in good condition and without loss.

Nos. 60 and 61. June 16. Culture experiments upon coagulated material filtered from beef broth, and on the beef itself after the broth had been extracted. The media were placed in common saucers, dusted with spores from agar culture No. 13, and covered with glass plates. Both were carefully examined each day until June 22 without finding any trace of the Sporotrichum.

Nos. 62 and 63. June 16–18. Infection experiments identical with No. 58. The grain lice (*Siphonophora avenæ*) treated in the same manner and from the same source of infection (No. 13). No results, except that one louse was dead with the fungus June

25, in No. 62. The insects in the checks all died in the meantime, but no traces of Sporotrichum appeared among them.

No. 64. May 22. Infection experiments on ten caterpillars and saw-fly larvæ (Tenthredinidæ), taken by sweeping grass. Treated with spores from the Thaxter culture (No. 7), and placed under a bell-glass on growing blue-grass and clover. Two saw-fly larvæ were dead on the 25th, and had a slight mycelial growth on their bodies; two more were dead with this fungus on the 26th; several more larvæ dead the following day; and on the 28th still others. May 30, all except two were dead and covered with Sporotrichum, and by June 4, these also had perished. Specimens preserved.

Other saw-fly larvæ enclosed in a similar cage without treatment remained in good condition and without loss.

No. 65. May 22. Infection experiment with larvæ of a grass saw-fly (Dolerus) taken by sweeping, with spores from the Thaxter culture (No. 7), and placed under a bell-jar on growing blue-grass and clover. May 26, two larvæ dead and covered with the fungus, together with a small fly (Dolichopodidæ) enclosed by accident; left in the cage to develop spores. May 28, more had died. May 30, all dead, and all except three with an external growth of Sporotrichum. Other specimens included with the above—an Apatura larva and several plant-lice—also dead with external fungous growth. Only a single lepidopterous caterpillar alive. Check of eight saw-fly larvæ from same place established May 29 and observed until June 9, by which time none had died, but all had pupated.

No. 66. May 25. Infection experiment on plant-lice collected from clover, treated with spores from the Thaxter agar culture (No. 7) and placed under a glass cylinder breeding-cage on clover plants. May 29, lice all alive. June 1, lice weak and wandering from food plant. June 3, all dead and imbedded in the white fungus. Specimens preserved. Check lot kept in similar cage remained in fair condition, a few lice dead; but there was no fungous growth on their bodies, and none appeared later. Experiment observed until June 5.

No. 67. June 1. Infection experiment with Cecropia moths treated with spores from the Thaxter tube (No. 7). Eight moths were dusted with spores, and placed in a breeding cage containing damp earth. By June 3, two had died, and all were dead by the 8th; but no external fungus on their bodies at this time. Four days later a slight mycelial growth appeared on several, which, by the 14th, was clearly Sporotrichum, and on the 18th was fruiting abundantly. Specimens preserved. Several dead moths with slight traces of Sporotrichum on their bodies were left in the cage. July 11, spores ripe. A similar number of moths kept under like conditions as a check, were all dead June 14, but developed no Sporotrichum.

No. 68. June 12. Culture experiment on corn-meal batter mixed with beef broth, prepared as in number 78. The nutrient material placed in a test-tube and infected with spores from culture No. 7. Two days later growth had begun, and it increased rapidly from day to day, spreading over the surface of the medium, and even penetrating the cracks and crevices where the meal had shrunken from the tube. A granular appearance was quite marked on the 17th, and spores were fully formed on the 22d. The surface had the characteristic yellowish appearance of maturity by the 23d; and the spores were easily detached by shaking on the 24th and 25th.

No. 69. July 8. Infection experiment with cabbage worms (*Pieris rapæ*), precisely similar to No. 36. The infection, however, in this experiment was derived from the preceding corn-meal culture (No. 68), and from a bran culture (No. 77) recorded farther on. One hundred worms were dusted with spores and placed on cabbage growing outdoors, which was then enclosed under a net-covered frame. The worms were somewhat restless the following day, and one pupated on the 10th. Several were sluggish, of a dark appearance, and not disposed to eat. Ants (Lasius) had attacked two larvæ that had fallen to the ground. July 11, twenty-two larvæ had pupated, and the others were all dead or dying. Ants still eating those on the earth. Pupæ, larvæ, and fragments placed on damp earth under a bell-glass. July 16, several butterflies emerged, and a number of hymenopterous parasites were removed on the 21st. Phoridæ developed in dead pupæ and were preserved. No traces of Sporotrichum seen at any time in the cage, or on the pupæ and larvæ removed and kept on damp earth. The check of twenty worms remained in fair condition.

No. 70. July 13. Infection experiment with chinch-bugs from Blue Mound, Illinois, treated with spores from cultures 68 and 72. Several hundred chinch-bugs were thoroughly dusted with Sporotrichum spores, and placed in a small wooden box, together with a supply of previously moistened green corn leaves for food. The box was securely covered, and fresh food introduced when needed. July 14, no Sporotrichum seen. July 20, a few bugs dead with visible fungus; and still others on the 22d. July 24, the number of bugs with Sporotrichum compared with the live insects in the box was very small. July 26, twenty-one bugs are imbedded in the white fungus; the attack does not seem to increase very rapidly. July 28, no more dead insects seen. The cage completely overhauled the 31st, and twenty-four fungus-covered bugs counted. A few dead without any external fungous growth. August 3, a few more dead with disease. Several adults pairing; a few eggs found on corn leaves; pupae not very abundant. August 7, no more fungus seen. August 10, a piece of middlings culture from No. 41, well covered with white fungus in a fruiting condition, was placed in the cage. Four days later a few bugs were dead with the disease. On the 16th, about the same number of dead were seen, the fungus was more abundant on the 19th, and little or no change was noted the 22d. Cage overhauled the 25th, and specimens dead with the white fungus picked out and preserved. Less than half the bugs dead at this time, and not all the dead showed an external fungus growth. August 31, a few more dead, but not much fungus visible. September 6, Sporotrichum more abundant, and dead bugs more numerous. Experiment closed September 14, number of fungus-covered bugs slightly increased.

No. 71. June 12. Culture experiment on sawdust mixed with beef broth, and sown with spores from the Thaxter agar culture, No. 7. The medium was prepared precisely as in experiments 39 and 40. No growth on the 14th; first growth noticed on the afternoon of June 15th. The fungus spread slowly and had penetrated the air spaces in the medium by the 17th; was very slightly granular by the 20th; and faintly yellowish by the 22d. Little or no change on the 25th. A slow start, sluggish growth, and scanty development of spores.

No. 72. June 12. Culture experiment like the preceding (No. 71), varying only in the nutrient material used, which was a batter of middlings mixed with beef broth, in this respect identical with No. 41. Fungus spores from the Thaxter culture (No. 7) were used to infect the medium. The fungous growth was visible the second day, and by the 18th had spread freely over the surface and was becoming granular and yellowish. The tube was opened on the 19th and part of the fungus was removed and used for infecting Nos. 73 and 74. That remaining in the tube continued to grow and completely covered the surface, spores being easily detached on the 24th.

No. 73. June 19. Infection experiment with Colorado potato beetles treated with spores from culture No. 72. The Sporotrichum of this culture was in a fruiting condition, but the spores were not easily detached by vigorous jarring. The beetles were infected by dipping them in water upon the surface of which the spores had been thrown, and were then placed in a breeding-cage with growing potato plant for food. A check lot was placed in a similar cage, and observed until July 6. Results purely negative, no Sporotrichum appearing at any time in either cage.

No. 74. June 19. Like No 73, except that crickets (Gryllus) were the subjects of the experiment and that they were infected by rolling them about in spores from culture No. 72. Maintained until July 6, with negative result. No Sporotrichum in either experimental lot or check.

The failure of the infection in this and the preceding case was probably due to the immature condition of the spores used for infection.

Nos. 75 and 76. July 10. Culture experiments on corn meal mixed with white and yolk of an egg. The nutrient material was placed in tumblers, dusted with spores from culture No. 72, and covered with glass. No fungous growth appeared. Experiments discontinued July 15.

For other experiments with white and yolk of an egg used as the nutrient material see Nos. 43 and 44.

No. 77. June 12. Culture experiment on bran mixed with beef broth, prepared and sterilized as in Nos. 53 and 54. Infected with Sporotrichum spores from No. 7. The mycelial threads appeared on the surface of the medium two days later, grew rapidly, and had begun to form spores by the 18th. A yellowish tinge, characteristic of ripeness, was barely apparent on the 19th; and spores were very easily detached by slight jarring on the 25th.

No. 78. July 7. Culture on corn meal and beef broth, infected with spores from the preceding bran culture, No. 77. Beef broth made by boiling one pound of beef in one quart of soft water for three hours. The broth was then filtered, and neutralized with carbonate of soda. A thick corn-meal batter, made by mixing the broth and meal, was placed in fruit-jars with altered caps (see Pl. V., Fig. 1), sterilized, and treated with Sporotrichum spores. July 8. Growth had begun July 10, and the surface of the medium was thoroughly covered on July 11. By the 16th, the surface was all covered, and by the 20th it had taken on the yellowish tinge of ripeness. Spores were easily detached on the 22d.

No 79. June 15. Culture experiment on corn meal saturated with beef broth without resort to sterilization, infected with Sporotrichum spores from No. 7. Meal spread evenly over the bottom of a shallow pan and thoroughly saturated with beef broth, which had been standing uncovered for three days, and hence was full of bacteria. Spores from the Thaxter agar culture were dusted over the surface of the medium, which was then covered with glass. A slight trace of the white fungus appeared June 16, but soon disappeared, and no further development of it was seen. Discontinued June 22.

Nos. 80 and 81. June 16. Culture experiments in the open air on a mixture of corn meal and beef broth, and corn meal and soft water, without the usual process of sterilization. The media were placed in tin pans, infected with spores from the Thaxter agar culture, No. 7, and then covered with glass. No Sporotrichum appeared at any time, and both cultures were discontinued June 22.

Nos. 82 and 83. June 17. Two open air culture experiments on corn meal saturated with modified Cohn's solution,* and dusted with fungus spores from No. 7. Experiment 82 was acidulated with one-twentieth of one per cent. and No. 83 with one-tenth of one per cent. of acetic acid. The nutrient material was placed in glass dishes, sown with spores of the white fungus, and then covered with a glass plate. Both masses were covered with molds on the 19th, and the experiments were discontinued on the 20th; no Sporotrichum having been seen.

No. 84. December 21. A test-tube culture experiment on corn-meal saturated with beef broth prepared as in No. 78, sterilized, and infected with spores of Sporotrichum from the Thaxter agar culture, No. 7. A slight mycelial growth appeared the 22d, but was not Sporotrichum. Several other fungi appeared in this tube, but no white muscardine up to January 15, 1892. The culture was again examined July 7, with the same result.

No. 85. June 1. A contagion experiment with live chinch-bugs from Litchfield, Illinois, confined with chinch-bugs dead with

*Distilled water 42.335 grammes, cane sugar 7.000 grammes, ammonium tartrate .250 grammes, potassium phosphate .125 grammes, magnesium sulphate .125 grammes, calcium phosphate .125 grammes. The purpose of this solution is to afford a suitable nitrogenous food for the growth of the fungus and at the same time to check bacterial development and the consequent appropriation of the food prepared for the fungus.

Sporotrichum disease, from experiment No. 2. Thirty chinch-bugs were placed in a breeding-cage, and exposed to infection forty-eight hours, from four fungus-covered bugs. June 10, three dead and covered with the fungus. All the whitened bodies removed and placed in a bottle. The live bugs remaining in the cage were now used for other experimental purposes.

In check lot, established the same time, no deaths.

No. 86 June 8. An infection experiment with young chinch-bugs, just past the second molt, dusted with spores of Sporotrichum, and then enclosed in a breeding-cage. The young bugs were treated with spores by being well shaken in a bottle, into which several bugs dead with the fungus of the white muscardine had been previously placed. Second infection, from other dead chinch-bugs, June 20. The experiment was a failure, as none of the young bugs were attacked by the fungus by June 30, and the check lot also remained without loss.

The diseased bugs used in this operation came from a stock cage kept in the insectary, supplied with chinch-bugs collected from wheat fields at Litchfield, June 2. June 5, several bugs in this cage were dead with white fungus, and the fungus attack increased in intensity up to, and including June 29. In the meantime, the fungus-covered bugs were removed and used for experimental purposes. The appearance of Sporotrichum in this cage was due to the presence of the spores when the insects were collected, or else they became infected from neighboring experimental lots. The former, however, seems quite probable, as dead chinch-bugs imbedded in this fungus were taken from the wheat at the time the collection was made.

No. 87. June 12. A test-tube culture experiment on corn meal and beef broth, prepared like No. 78, and at the same time. The medium was infected with spores from a chinch-bug dead with white muscardine, originally from the same source as those used in 86. The fungus-covered bug was dropped into a tube, where it remained upon the surface of the culture for a short time, and was then removed. Two days later a slight mycelial growth of the white muscardine appeared, spread rapidly, and almost completely covered the surface of the medium by the 17th. A blue mold appeared in the bottom of the tube at this time. June 18, Sporotrichum same as yesterday; blue mold spreading. June 20, Sporotrichum spore-clusters beginning to form. June 22, the fungus had the characteristic yellowish appearance of maturity. June 24, blue mold appeared in the upper part of the tube. Sporotrichum thoroughly ripe and in good condition June 27. Culture affected by bacteria, producing a reddish discoloration about and beneath the moldy spots.

Nos. 88, 89, 90, and 91 June 12, and 30. These are successive test-tube culture experiments on bran, middlings, saw-dust, and corn meal mixed with beef broth, prepared and sterilized like No. 68. The fungus covered bugs used to infect these tubes came from the same source as those used in 86 and 87. The bugs were placed in the tubes and rolled over the surface of the media for a few minutes and then removed. Sporotrichum failed to germinate, and the tubes were filled with a profuse growth of mold.

No. 92. June 30. A test-tube culture on corn meal mixed with beef broth as in No. 68. A chinch-bug dead with Sporotrichum, originally from Blue Mound, Illinois, was used to infect this tube. The fungus, however, was in a fruiting condition, but the spores were not thoroughly ripe. A feeble growth of Sporotrichum appeared July 3, but was soon crowded out by a profuse growth of mold which took possession of the medium.

No. 93. July 3. Test-tube culture experiment on corn meal mixed with beef broth, sterilized at a temperature varying from 100° to 107° Cent. for thirty-five minutes. Two tubes were prepared and treated with fungus spores from beetles (Lachnosterna and Diabrotica) and a myriapod found in earth near Urbana, Illinois, June 2, 1891. The spores were introduced into the tube by means of a sterilized platinum wire. A slight mycelial growth of the white muscardine appeared on the surface of each culture July 5. Sporotrichum was spreading over the medium on the 8th, but other fungi had appeared and were also spreading. Sporotrichum was more plentiful the 10th, and other fungi growing about as rapidly. By the 18th, the intruding fungi had crowded out the white fungus in one tube and by the 24th had completely choked and hidden it in the other.

No. 94. July 16. A test-tube culture on a mixture of corn meal and beef broth, prepared and sterilized as for No. 93. The fungus spores used in this experiment came from thistle caterpillars (*Pyrameis cardui*), collected from thistle (*Cirsium lanceolatum*) near Urbana, June 30, and placed in a breeding-cage in the insectary. The fungus of white muscardine appeared spontaneously on both larvæ and pupæ of this lot about July 8. Sporotrichum had begun to grow on the culture medium July 18, and increased rapidly, having spread over the greater part of the culture surface two days later. The growth was quite granular, and of a yellowish tinge (indicating ripeness) by the 24th. Spores from this tube were used in the successful culture immediately following (No. 95), and in subsequent culture experiments made in 1892 (Nos. 2, 3 and 26; Jan. 5, March 12, 22).

No. 95. December 21. A test-tube culture from No. 94 on a batter of corn meal and beef broth prepared like No. 94, except that the tube was sterilized for three-quarters of an hour at a temperature of 100° Cent. A profuse growth of Sporotrichum appeared two days later, and by the 28th had covered the greater part of the nutrient material. A few spores were beginning to form on the 30th, and by January 4 (1892), the characteristic yellowish tinge, indicating ripeness, appeared. A few spores were easily detached by shaking. By the 11th, a fruiting growth of Sporotrichum had completely covered the entire surface of the medium.

No. 96. July 21. A contagion experiment with chinch-bugs exposed to infection by means of fungus-covered chinch-bugs received from Dr. Snow July 18. Several hundreds of bugs collected at Litchfield July 18 were placed in a tight wooden box with the dead chinch-bugs and supplied with fresh food from time to time. The first dead bug in this lot was seen August 3, and gave no external evidence of infection. August 16 two were seen in this cage covered with Sporotrichum. A few other whitened bodies were found on the 19th, 22d, and 25th. Between the latter date and the 31st little or no change took place. A slight apparent increase of the infection was noted September 6, but there was no further progress of the disease apparent by the 30th of that month. The box was then restocked with about two hundred and fifty live chinch bugs originally obtained at Litchfield September 23. Nothing further was noted in this box to indicate a progress of disease until December 8, when a few bugs were seen with a fresh growth of Sporotrichum on their bodies.

No. 97. July 21. A contagion experiment arranged precisely as the above (No. 96) except that the bugs used for infection (received also from Dr. Snow) had died as a result of parasitism by *Empusa aphidis*. In this box also no dead bugs were seen until August 3, and then only a few, without trace of any external fungus growth. On the 14th of August, a small number were seen with a fresh growth of Sporotrichum on their bodies, but none with Empusa. Several others dead at this time bore no external fungous growth. August 22 a considerable number of eggs were noticed in the cage, and more than half the bugs were dead, very few or them, however, with any external fungous growth. Similar notes were made on the 31st of August and on the 6th and 14th of September. On the 29th, only eighteen live bugs were found in the box, and on those dead there was no external growth of Empusa, a small number showing Sporotrichum only.

A check on the two preceding experiments (96, 97) was separated the same day, July 21, and kept under precisely similar conditions. One bug dead with Sporotrichum was removed August 3. A few adults were seen pairing, and several eggs were found on leaves, some of them shriveled and dried up. No fungus on any of the enclosed bugs at any later date. The spontaneous appearance of Sporotrichum in this box shows that it was brought with them from the field, or that they became infected from other experiments in the same building.

No. 98. August 7. A chinch-bug contagion experiment with live chinch-bugs received from Dr. Snow on this date. About seventy-five live bugs were placed in a small sack of Swiss muslin and supplied with green corn leaves for food. The bugs dead with Empusa, used in the preceding experiment (No. 97), were removed from that cage and placed in the sack just mentioned, which was then enclosed in contagion box No. 97. Fresh food was introduced into the sack when needed. One dead bug, showing an external growth of Sporotrichum, was seen August 15, several others had died and were covered with the same fungus the 17th, and still others were seen the 22d and 31st. Only fifteen live bugs remained in the cage September 14, and these were all dead, except one, on the 28th. The fungus-covered bugs were removed August 22 and September 14. Those taken out on the former date contained an unmistakable growth of Sporotrichum, while those removed the latter date were imbedded in a mixed growth which was not definitely determined.

Unfortunately, however, for the significance of these results, about half the specimens from the check originally separated, had perished with the Sporotrichum disease, thus giving evidence either that the original lot from Dr. Snow had been diseased when taken, or else that the check had become infected from the neighboring experimental lots.

No. 99. July 21. A contagion experiment precisely similar to No. 96, except that the infection used consisted of bugs said to have died from a "mixed disease" (Sporotrichum and Empusa), which were received from Dr. Snow on the same day as those used in the two experiments immediately preceding. Fresh food was introduced into the cage when needed. A few dead bugs were seen July 28, but none with fungus. August 3, cage overhauled. A few bugs seen pairing and several eggs found on leaves. A few dead with fungus, probably Sporotrichum. Two more bugs dead with the fungus were removed on the 7th. Several with a fresh fungous growth on their bodies were noted on the 14th, and still others on the 16th, 19th, and 22d. By the 25th, nearly three fourths of the bugs were dead, and the great majority of them were covered with the white fungus. More bugs dead with fungus were seen September 6, and others on the 14th. Only four live bugs remained the 25th. A careful examination of the fungus-covered bugs removed showed that Sporotrichum was the only fungus present. The check upon this experiment was the same as that for Nos. 96 and 97.

No. 100. August 7. A contagion experiment precisely similar to No. 98, except that the diseased bugs used came from experiment No. 99. Fresh food was introduced into the sack when needed. A few bugs dead with Sporotrichum were seen on the 17th, and about two-thirds of the entire lot were dead by the 22d, one-half of them being covered with fungus. Eggs were seen in small numbers, and two imagos *in coitu* were found dead with the white fungus. Still others were dead the 25th, and all had died by September 9, most of them imbedded in Sporotrichum.

The check upon this experiment was the same as that for No. 98, and the results obtained are therefore not very significant, as it is quite likely that the live bugs used were diseased when received.

No. 101. December 22. A test-tube culture on corn meal and beef broth mixed to a thick batter, sterilized for three quarters of an hour at a temperature of 100° Cent., and then treated with Sporotrichum spores from the femur of *Pezotettix differentialis*, originally found at Urbana, Illinois, September 16. There was a visible Sporotrichum growth in the tube December 24, and the surface of the medium was completely covered four days later, at which time other fungi made their appearance in the tube. These finally took possession of the medium, and by January 14, 1892, had suppressed the Sporotrichum and filled the tube.

THE YEAR 1892.

The experimental work upon the contagious diseases of insects during the year 1892, was practically a continuation of that of the preceding year, differing from the latter especially in the fact that in addition to work with *Sporotrichum globuliferum*, experiments were made with two other entomogenous fungi—*Botrytis tenella* and *Isaria leprosa;* that a beginning was attempted with field experiments with Sporotrichum upon chinch-bugs; that the laboratory contagion and infection experiments were extended to a large number of additional species of injurious insects; that cultures on agar were studied with reference to the rate of growth and development of Sporotrichum upon that medium; and that several cultures were made for the purpose of ascertaining the length of life of the dry spores of Sporotrichum.

The scarcity of the chinch-bug in parts of the State readily accessible to us, made the field contagion experiments of little effect; and the culture experiments, with the exception of those made for the purpose of testing the persistent vitality of fungus spores, were mostly made merely to provide a supply of spores for use in making infection experiments on various insects, or else were sequent to such experiments, whose results they were intended to verify.

The agar cultures gave us, as might have been anticipated, substantially the same rate of development of Sporotrichum as that ascertained for corn-meal cultures in 1891, visible growth occurring on the second or third day after the sowing of the spores, noticeable development of heads of spores appearing at about the seventh day, and the first conspicuous ripening ranging from seven to fifteen days. It is to be noticed that cultures made in March and October, developed much more slowly than those made in July. As no effort was made at temperature control, these various experiments were, of course, affected by the weather of the season. The spores of *Sporotrichum globuliferum* were proven by experiments 1 and 2 to live at least six months when thoroughly well dried out; by experiment 3 to live eight months; and by experiments 27 and 49 to be capable of generous growth after nine months of dessication. On the other hand, in Nos. 69 and 70 are recorded failures of germination under entirely favorable conditions after eleven months' drying out.

A single experiment (No. 23) gave the interesting information that these little spores may germinate in water in a few hours, and that a considerable growth of hyphæ may be made within twenty-four hours.

A point of notable interest in the life history of *Sporotrichum globuliferum* was brought out by an infection experiment upon white grubs referred to under No. 51. These insects, buried lightly in the earth after death by muscardine, threw out upon the surface of the ground a delicate sheet or mat of mycelial growth, which ultimately bore spores abundantly upon its free margin. (See Pl. VII., Fig. 8, 9.) The identity of this remarkable Isaria form with the original Sporotrichum, was demonstrated by agar cultures 52 and 54, which gave again the Botrytis form usual in artificial cultures. This fact was further verified by repeated cultures from these tubes, namely, 53, 55, 56, and 57, all of which consisted wholly of unmistakable *Sporotrichum globuliferum*.

As a result of the laboratory infection experiments with Sporotrichum on the chinch-bug. it appeared that while most of these were successful, several of them were only doubtfully so, the insects treated dying in confinement but without any subsequent external fungous growth.* The method used was imperfect, however, as these dead specimens should have been kept for four or five days on damp sand in a damp atmosphere and at a suitable temperature.

THE FIELD INFECTION EXPERIMENTS.

Our experiments with *Botrytis tenella* all depend upon three tubes of that fungus received from MM. Fribourg & Hesse, of France, a firm of chemists who advertised this fungus for sale as an insecticide especially recommended for the destruction of the *ver blanc*, representative, in the agriculture of Europe, of the white grub of America. The spores from which their cultures were made were understood to have been obtained from Prof. A. Giard, of Paris. The material came to us in glass tubes stopped with cotton at one end, the first of them January 5 and the two others February 19. In addition to the fungus spores, these tubes evidently contained a good deal of foreign matter resembling meal, which however we did not attempt to determine. The mass was also impure from a botanical standpoint in all the tubes, containing a considerable quantity of blue mold, and presenting reddish discolorations in spots, as if by a bacterial infection. The results of our experiments show, however, that the tubes also contained living spores of *Botrytis tenella*. The tubes received in February were reported by the senders to have come from cultures freshly made that year.

A tube received May 25 from Prof. Thaxter—itself a culture from material obtained from Prof. Giard, of Paris—was used by us only as a starting point for cultures 75 and 79 of the following list.

All our cultures from the first tube received, that of January 5, were failures, owing to the extreme impurity of the growths. In some cases a mycelium grew which presented the general appearance of *Botrytis tenella*, but it was speedily overcome by more vigorous fungi, and was suppressed without fruiting. There can be no question, however, that the *Botrytis* spores were present even in this first sending, since infection experiments, although not entirely satisfactory, resulted in a few cases in the killing of larvæ with the subsequent reddish discoloration characteristic of the action of this fungus. The second sending was more satisfactory, although still impure. Growths of Botrytis appeared in some of the tubes in sufficient abundance to hold their own, and by transfer of these

* For further light on the cause of such losses of bugs not visibly infected, see experiment 72, series of 1894.

to other tubes fairly clean cultures were obtained. Infection experiments with this better material were successful on white grubs and Bibio larvæ, and possibly upon chinch-bugs also. In general, however, this Botrytis compared unfavorably with Sporotrichum so far as our experiments extended.

March 21, a tube of *Isaria leprosa* was received from Prof. Thaxter, with the suggestion that it be tested as an insecticide. This tube—whose previous history is unknown to me—was used only as a source of infection for several cultures made in the bacteriological laboratory of the University, and from these our experimental material was wholly drawn. Infection experiments with these cultures promise better results for this fungus than for *Botrytis tenella*. Two such experiments on white grubs and one on caterpillars of Lepidoptera had a successful issue, while an infection of chinch-bugs was apparently without result.

CLASSIFIED LIST OF EXPERIMENTS—1892. NOS. 1—86. *Experiments with Sporotrichum Globuliferum.*

Cultures on agar-agar:

No. 3. March 22. From corn-meal culture of 1891 (No. 94).
No. 69. March 22. From original Thaxter culture (No. 7, 1891).
No. 70. March 24. From original Thaxter culture (No. 7, 1891).
No. 71. May 5. From dead chinch-bugs.
No. 72. May 11. From dead chinch-bugs.
No. 76. May 17. From Euschistus dead in field.
No. 77. November 17. Agar culture from No. 76.
No. 52. July 8. From white grub experiment, No. 51.
No. 54. July 15. From white-grub experiment, No. 51.
No. 55. July 15. From No. 54, second remove from grub.
No. 82. July 20. From dead chinch-bugs; northern Illinois.
No. 84. November 15. Spores from dead beetles found in the field November 8.
No. 56. October 31. From No. 55, third remove from grub.
No. 53. November 17. From No. 52, second remove from grub.
No. 57. November 17. From No. 56, fourth remove from grub.

Cultures on corn-meal mixtures:

No. 26. March 12. Fruit-jar culture. Spores from 1891 series (14, 31, and 94). Second remove from insect.
No. 27. March 14. Fruit-jar culture. Spores from 1891 series (14, 32, 47, 50, and 94). Second remove from insect.
No. 49. March 14. Test-tube cultures from 1891 series (7 and 14).
No. 50. April 11. Fruit-jar culture. Spores from No. 49.
No. 73. July 7. Fruit-jar culture from agar culture 72, second remove from chinch-bug.

Cultures on flour paste:

No. 1. January 5. From series of 1891 (Nos. 31, 47, and 50).
No. 2. January 5. From series of 1891 (No. 94).

Infection and contagion experiments:

No. 29. April 7. Infection of chinch-bugs. Spores from corn-meal cultures 26 and 27. Second remove from insect.

No. 30. April 20. Infection of chinch-bugs. Spores from corn-meal cultures 26 and 27.

No. 34. May 10. Farmer's chinch-bug contagion-box. Infection by spores from 26 and 27.

No. 35. May 11. Farmer's chinch-bug contagion-box. Infection by spores from 26 and 27.

No. 48. August 15. Infection experiment with chinch-bugs. Spores from 26 and 27.

No. 42. August 15. Contagion experiment with chinch-bugs. From dead Vanessa larva out of experiment 41.

No. 83. August 15. Infection of chinch-bugs. From agar culture.

No. 81. July 19. Farmer's field contagion experiment with chinch-bugs.

No. 33. June 20. Contagion experiment with grass-bug (*Ischnodemus falicus*). Spores from beetles out of No. 32.

No. 37. June 20. Infection experiment with grass-bug (*Ischnodemus falicus*). Spores from Nos. 26 and 27. Second remove from insect.

No. 74. June 20. Contagion experiment with Ischnodemus. Spores from dead chinch-bugs.

No. 39. June 21. Infection experiment with Ischnodemus. Spores from 26 and 27.

No. 40. June 21. Outdoor infection experiment with Ischnodemus. Spores from 26 and 27.

No. 47. August 8. Contagion experiment with leaf hoppers and other insects. Spores from 26 and 27.

No. 51. May 9. Infection of white grubs. Spores from corn-meal culture No. 49. Second remove from insect.

No. 46. August 8. Infection of cabbage worms. Spores from 26 and 27.

No. 45. July 26. Infection of army worms (*Leucaniau nipuncta*). Spores from 26 and 27.

No. 43. July 5. Infection of caterpillar *Papilio asterias.* Spores from 26 and 27.

No. 80. June 28. Contagion experiment with caterpillars of *Vanessa antiopa.* Spores from Datana larvæ out of No. 51, series of 1891.

No. 41. June 28. Infection experiment with caterpillars of *Vanessa antiopa.* Spores from 26 and 27.

No. 36. June 6. Infection experiment with Cecropia moths. Spores from 26 and 27.

No. 38. June 20. Infection experiment with various Diptera. Spores from 26 and 27.

No. 32. May 4. Infection of various beetles (larvæ and adults of Silphidæ and Dermestidæ). Spores from 26 and 27.

No. 31. May 4. Infection of miscellaneous insects. Spores from 26 and 27.

No. 44. July 15. Infection of miscellaneous insects (mostly grasshoppers). Spores from 26 and 27.

Experiments with Botrytis Tenella. Artificial Cultures.

Cultures on agar-agar:

No. 5. January 11. Spores from imported material.
No. 9. February 22. Spores from agar culture No. 5.
No. 6. March 19. Spores from agar culture No. 5.
No. 7. April 21. Spores from agar culture No. 6.
No. 13. May 7. Spores from white grub from No. 12, dead by infection from imported fungus.
No. 78. May 25. Spores from original culture by Prof. Thaxter.
No. 79. July 7. Spores from original culture by Prof. Thaxter.
No. 14. June 6. Spores from agar culture No. 13.
No. 15. June 29. Spores from agar culture No. 14.
No. 16. July 6. Spores from agar culture No. 13.
No. 22. July 8. Spores from dead white grub out of experiment 21.
No. 20. October 31. Spores from agar culture No. 16.
No. 25. November 17. Spores from Paris importation.
No. 86. November 25. Spores from agar culture No. 20.

Cultures on corn-meal mixtures:

No. 4. January 11. Spores direct from Paris importation.
No. 8. February 22. Spores direct from Paris importation.

Culture on potato:

No. 10. February 23. Spores from agar culture No. 5.

Infection and contagion experiments:

No. 18. August 15. Infection of chinch-bugs. Spores from agar culture No. 16.
No. 24. October 31. Infection of plant bugs (Anasa and Euschistus).

Spores direct from Paris importation.

No. 12. March 31. Infection of white grubs. Spores from Paris importation.
No. 21. May 25. Infection of white grubs. Spores from Paris importation.
No. 19. August 26. Infection of white grubs. Spores from agar culture No. 16.
No. 64. May 9. Contagion experiment with white grubs. Exposed to dead grubs from No. 12.
No. 17. August 8. Infection of tomato worms (Protoparce). Spores from agar culture No. 16.
No. 23. July 13. Infection experiment with clover insects. Spores from Paris importation.
No. 11. March 11. Infection of Bibio larvæ. Spores from Paris importation.

Experiments with Isaria leprosa.

Cultures on agar-agar:

No. 65. April 19. Spores from Thaxter tube.
No. 66. June 3. Spores from agar culture No. 65.
No. 62. July 7. Spores from Thaxter tube.
No. 59. July 8. Spores from grub out of No. 58.
No. 63. October 31. Spores from Thaxter culture of March 21.
No. 67. November 3. Spores from agar culture No. 66.
No. 61. December 13. Spores from agar culture No. 59.

Infection experiments:

No. 60. July 25. Infection of chinch-bugs. Spores from agar culture No. 59.

No. 85. April 19. Infection of white grubs from agar culture.

No. 58. May 25. Infection of white grubs. Spores from agar culture.

No. 68. December 16. Infection of lepidopterous pupæ. Spores from agar culture No. 67.

Experiments with Entomophthora.

No. 75. May 6. Infection of plant-lice with *Entomophthora aphidis* from chinch-bugs.

Miscellaneous Cultures.

Nos. 76, 77, and 84 are agar cultures of various fungus parasites found dead on insects taken in the field.

OUTLINE OF EXPERIMENTS WITH FUNGUS PARASITES OF INSECTS, 1892.

Sporotrichum globuliferum.

No. 1. January 5. Wheat-flour culture from 1891 series (31, 47, 50).

No. 2. January 5. Wheat-flour culture from No. 94 of 1891 series.

No. 3. March 22. Agar culture. Spores from No. 94 of 1891 series.

No. 26. March 12. Corn-meal culture from 1891 series (14, 31, 94).

No. 27. March 14. Corn-meal culture from 1891 series (14, 32, 47, 50, 94).

No. 29. April 7. Chinch-bug infection experiment.

No. 30. April 20. Chinch-bug infection experiment.

No. 31. May 4. Infection of miscellaneous insects.

No. 32. May 4. Infection of larvæ of adult beetles.

No. 33. June 20. Contagion experiment with *Ischnodemus falicus.*

No. 34. May 10. Farmer's field contagion experiment.

No. 35. May 11. Farmer's field contagion experiment.

No. 36. June 6. Infection experiment with Cecropia moths.

No. 37. June 20. Infection experiment with Ischnodemus.
No. 38. June 20. Infection experiment with Diptera.
No. 39. June 21. Infection experiment with Ischnodemus.
No. 40. June 21. Infection experiment with Ischnodemus.
No. 41. June 28. Infection experiment with caterpillar of Vanessa.
No. 42. August 15. Contagion experiment with chinch-bugs.
No. 43. July 5. Infection experiment with caterpillar of Papilio.
No. 44. July 15. Infection experiment with miscellaneous insects.
No. 45. July 26. Infection experiment with army worm.
No. 46. August 8. Infection experiment with cabbage worms.
No. 47. August 8. Contagion experiment with miscellaneous insects.
No. 48. August 15. Contagion experiment with chinch-bugs.
No. 28. March 30. Moisture experiment with spores.
No. 49. March 14. Corn-meal culture. Spores from 1891 series (7, 14).
No. 50. April 11. Corn-meal culture.
No. 51. May 9. Infection experiment with white grubs.
No. 52. June 8. Agar culture.
No. 53. November 17. Agar culture.
No. 54. July 15. Agar culture.
No. 55. July 15. Agar culture.
No. 56. October 31. Agar culture.
No. 57. November 17. Agar culture.
No. 69. March 22. Agar culture from No. 7, 1891.
No. 70. March 24. Agar culture from No. 7, 1891.
No. 71. May 5. Agar culture from dead chinch-bugs.
No. 72. May 11. Agar culture from dead chinch-bugs.
No. 73. July 7. Corn-meal culture.
No. 74. July 20. Contagion experiment with Ischnodemus. Spores from dead chinch-bugs.
No. 76. May 17. Agar culture from Euschistus.
No. 77. November 17. Agar culture.
No. 80. June 28. Contagion experiment with caterpillars of Vanessa. Spores from No. 51, 1891.
No. 81. July 19. Farmer's field contagion experiment.
No. 82. July 20. Agar cultures from chinch-bugs dead in the field.
No. 83. August 15. Infection experiment with chinch-bugs. Spores from undetermined agar culture.
No. 84. November 15. Agar culture from beetle dead in field.

Botrytis tenella.

No. 4. January 11. Corn-meal culture from Paris importation.

No. 5. January 11. Corn-meal culture from Paris importation
No. 6. March 19. Agar culture.
No. 7. April 21. Agar culture.
No. 9. February 22. Agar culture.
No. 10. February 22. Culture on raw potato.
No. 11. March 11. Infection experiment with Bibio larvæ. Spores from Paris importation.
No. 12. March 13. Infection of white grubs (Polymœchus and Serica). Spores from Paris importation.
No. 13. May 7. Agar culture.
No. 14. June 6. Agar culture.
No. 15. June 29. Agar culture.
No. 16. July 6. Agar culture.
No. 17. August 8. Infection of tomato worm.
No. 18. August 15. Infection of chinch-bugs.
No. 19. August 26. Infection of white grubs.
No. 20. October 31. Agar culture.
No. 86. November 25. Agar culture.
No. 64. May 9. Contagion experiment with white grub.
No. 21. May 25. Infection experiment with white grubs.
No. 22. July 8. Agar culture.
No. 23. July 13. Infection of clover insects.
No. 24. October 31. Infection of plant-bugs.
No. 25. November 17. Agar culture.
No. 8. February 22. Corn-meal culture from Paris importation.
No. 78. May 25. Agar culture from Thaxter. Original infection from Giard.
No. 79. July 7. Agar culture from Thaxter. Original infection from Giard.

Isaria leprosa.

No. 58. May 25. Infection experiment with white grubs. Spores from agar culture.
No. 59. July 8. Agar culture.
No. 60. July 25. Chinch-bug infection.
No. 61. December 13. Agar culture.
No 62. July 7. Agar culture from Thaxter tube.
No. 63. October 31. Agar culture from Thaxter tube.
No. 65. April 19. Agar culture from Thaxter tube.
No. 66 June 3. Agar culture.
No. 67. November 3. Agar culture.
No. 68. December 16. Infection experiment with lepidopterous pupæ
No. 85. April 19. Infection experiment with white grubs. Spores from agar culture.

DETAILED DESCRIPTION OF EXPERIMENTS, 1892.

No. 1. January 5. A fruit-jar culture on wheat flour and beef broth, and corn meal and beef broth, so managed as to afford a large surface area in a small space. A half-gallon jar was first coated inside with a thin paste of flour and water, which was allowed to dry, and was then given a second coat of flour paste to which a little beef broth had been added. Several tin-box lids strung on a wire, filled with a batter of corn meal and beef broth, were then suspended from the cover, after which the jar was closed and sterilized for fifty minutes in boiling water, and infected, through the tube, with spores from cultures 31, 47, and 50 of the series for 1891.

January 11. A good growth of Sporotrichum covered the corn meal, but was less vigorous on the wheat flour on the sides of the jar. Two days later the fungus in the cups was in fruit, but the precise condition of the growth on the side of the jar could not be ascertained, owing to the opacity caused by the paste. Bacteria appeared in the jar January 16, and four days later had spoiled the experiment.

No. 2. January 5. A test-tube culture on a paste of wheat flour and beef broth sterilized at a temperature of 100° Cent. and treated with fungus spores from corn-meal culture No. 94, started July 16, 1891. By January 11 Sporotrichum was quite abundant on the thicker parts of the medium; but the growth had become impure by the 16th. It was not at any time so profuse as that on corn meal and beef broth. Wheat flour was not regarded as a good material for these cultures. It will be noticed that the spores for this infection were more than six months old.

No. 3. March 22. A test-tube culture on agar prepared according to the usual formula, and treated with spores from corn-meal culture No. 94, series 1891, now almost eight months old. This old culture mass had become dry and hard, and rattled against the sides of the tube like a piece of bone. Its spores were, however, in good condition, and an abundant mycelial growth was plainly visible in the new tube March 25, three days from the time of sowing. This was still increasing on the 28th, and spores were beginning to form on the 29th. The Sporotrichum continued to grow, and the spores had begun to ripen April 5. Many were easily detached by shaking April 8, and all seemed ripe by the 15th.

No. 4. January 11. A test-tube culture on corn meal and beef broth sterilized for forty minutes at a temperature of 100° Cent., and infected with spores of *Botrytis tenella* from the Fribourg & Hesse culture previously described (see p. 61). The infection was made by quickly removing the cotton plug of the tube and transferring the spores on the end of a platinum wire which had been recently heated to redness. A white mycelium appeared promptly, and was already quite abundant by January 13, but greenish and pinkish tinges appeared in it the following day, indicating an impure culture. A slimy mold also sprang up, which by the 20th had practically suppressed everything else in the tube. When the culture was thrown out, January 25, no trace of *Botrytis* was to be detected in it.

No. 5. January 11. Two test-tube culture experiments on agar, prepared exactly alike and at the same time, sterilized and treated with spores of Botrytis from the Fribourg & Hesse culture. A white mycelium was visible the following day, which had begun to fruit by January 13, presenting the general naked-eye characters of Botrytis. It was evident, however, the next day that the culture was impure, a greenish fungus and a reddish bacterial contamination appearing. The culture was kept until the 30th and then rejected as without value.

No. 6. March 19. An agar tube infected with spores from No. 5, from a portion of the growth taken at the time to be *Botrytis tenella*. The culture resulting proved, however, to be a green mold, which was followed later by another foreign growth. Examination on the 30th showed no *Botrytis tenella* in this tube.

No. 7. April 21. An agar culture with spores from the culture immediately preceding. Five days later a greenish fungous growth had fruited, but no Botrytis was seen. Tube emptied on the 30th; still no Botrytis.

No. 8. February 22. A test-tube culture on corn meal and beef broth sterilized for half an hour at 100° Cent., and treated with spores of *Botrytis tenella* from the culture received from Fribourg & Hesse, February 19. A slight mycelial growth was seen February 24, which had increased considerably by the 26th, and formed white tufts over the surface of the medium. This developed later into a blue mold, and further evidence of a mixed contamination presently appeared. The culture was, however, allowed to continue until the 20th of March, at which time its various fungous growths were microscopically examined. There was no *Botrytis tenella* in this tube.

No. 9. February 22. A test-tube culture on agar sterilized and treated with spores from the same source as those used in experiment 8. Like the preceding, a mixed growth of various fungi, among which no *Botrytis tenella* matured.

No. 10. February 28. Culture experiments on raw potatoes treated with spores of *Botrytis tenella* from the same source as those used in the two preceding experiments. The spores were dusted over the cut surface of raw potatoes, and kept under bell-glasses placed over dishes containing water. Results purely negative.

No. 11. March 11. An infection experiment upon Bibio larvæ dusted with spores of *Botrytis tenella*. A large number of larvæ were placed in a shallow tin pan and dusted with the contents of one of the tubes received from Fribourg & Hesse. The pan was then covered with a moist paper and another pan. Nothing of importance was noted until the 20th, at which time the larvæ were beginning to pupate. On the 30th one larva showing a white mycelial growth and a pupa of a pinkish tint were dead. There were several dead larvæ in the cage at this time, but no others showed any traces of fungus on their bodies. By the 31st those which were of a pinkish tint at first had become covered with a whitish mycelium. Several imagos emerged April 2. Two more dead pupæ of a pinkish tint were seen the 4th. Several other dead larvæ and pupæ were seen at this time, but no fungus was present on them. On the 5th two more pinkish larvæ were seen. Nearly one third of the larvæ had now become imagos. By the 7th a whitish growth of fungus of a pinkish tint had appeared on all the larvæ and pupæ, and spores had begun to form by the 12th, being apparently ripe on one specimen by the 14th.

A number of larvæ from the same source were kept under similar conditions as a check. No fungus appeared in the check at any time, and nearly all had emerged as imagos by April 14.

No. 12. March 31. Fifty white grubs (most of them *Polymœchus brevipes* and the remainder *Serica vespertina*) taken from a rotten oak log at Urbana, Ill., were thoroughly dusted with a portion of the contents of one of the tubes from Fribourg & Hesse, and were placed in an earthen dish with a quantity of the rotten wood. A check lot was established under similar conditions, but not dusted with spores. The first effect of the treatment was observed April 6, when a single larva each of Serica and Polymœchus was found dead, the latter with a flabby thorax and the abdomen somewhat hard. This lot of larvæ was examined at intervals of two days, and April 8 one more was found dead, April 10 sixteen, on the 12th seventeen, on the 14th one, on the 16th three, on the 18th four, and finally, May 2, five more—making forty-nine in all.

Infection by this fungus is unmistakably indicated by a pale pink tint of the dead larvæ, deepening to a definite rosy color, which disappears, however, with the development of spores upon the surface of the grub. This characteristic color was shown by twenty of the above larvæ, the first exhibiting it April 8. It was noticed that the Serica larvæ, although seemingly affected like the others, did not change color in this way. An external mycelium was first shown April 16, on a grub which had died on the 8th and had then been transferred to damp sand and covered with a bell-jar. Others showed this external growth on the 18th and 20th, while spores first appeared April 26. From such spores successful cultures were made in test-tubes of agar-agar, the culture medium assuming the deep red color to which this fungus gives rise. Proof was consequently complete of the destruction of at least a considerable number of these grubs by a thorough infection with spores of *Botrytis tenella*. In the check, in the mean time, three larvæ had died, one on the 14th and two on the 18th of April —all of them, however, without any appearance of fungous affection.

No. 13. May 7. Several test-tube agar cultures, the spores derived from one of the white grubs dead as described in experiment 12. Visible growth of Botrytis in two days, but an impure culture in every tube. Contaminated with bacteria and various foreign fungi. Several of these tubes were thrown out, but from one all the growths not resembling Botrytis were removed with sterilized tools, and the glass above the agar was heated in the flame of an alcohol lamp. The Botrytis, which had begun to grow May 9, developed freely, and May 11 was coloring the agar red. It was in a fruiting condition May 21, and bore an abundance of thoroughly ripened spores by the 25th, some of which were used in experiments 14 and 16.

No. 14. June 6. Test-tube cultures on agar treated with spores from agar culture No. 13. Mycelial growth showed plainly two days later, and the agar already had a reddish tint. The fungus spread rapidly and had begun to fruit by the 14th, at which time the greater part of the agar had become dark red. Spores ripe on the 18th and the agar losing its reddish color.

No. 15. June 29. An agar culture infection from No. 14. Visible growth July 2, small red spots in agar around the tufts of mycelium. July 7, agar nearly all red, with dark brownish spots where the mycelium is attached. July 9, red color of the agar had begun to fade, and by the 11th it had all disappeared. The fungous growth in the meantime had assumed a peculiar grayish tint, indicative of ripeness of the spores.

No. 16. July 6. Agar cultures in six tubes infected from No. 13. July 7, no visible growth. July 9, a white mycelium has started. July 11, mycelium spreading rapidly; agar entirely red. July 14, color unchanged; mycelium pure white and dense. July 15, spore heads visible. July 18, color of agar beginning to fade. On the 23d, spores ripe; red color of agar practically all gone.

No. 17. August 8. An infection experiment upon tomato worms (Protoparce) treated with spores of Botrytis from agar culture 16. Eight larvæ were treated by rubbing the spores into the spiracles with a small brush, and placed in a breeding-cage. They all entered the ground on the 15th to pupate, and the moths emerged a little later. No fungus appeared.

No. 18. August 15. An infection experiment with *Botrytis tenella* on chinch-bugs, the latter obtained from Forreston, Illinois, August 13. Several hundred live bugs were shaken up in a test-tube agar culture (No. 16) until their bodies were covered with spores. They were then put into a wooden box, supplied with food, and set on damp sand in a shady place in the insectary. None dead on the 18th, but several pupæ had transformed to the imago. By the 21st several bugs had died, and a few showed a mycelial growth upon the surface, which proved, however, on microscopic examination to be a common mold bearing no resemblance to Botrytis. More bugs died on the 29th, but no *Botrytis tenella* in the cage. Experiment abandoned.

No. 19. August 26. An infection experiment with white grubs dusted with spores of Botrytis from culture No. 16. Nineteen grubs were well dusted with spores and placed in a breeding-cage with grass roots for food. No fungus had appeared by September 4, and the grubs were in good condition. One was dead the 15th, but contained no fungous growth. Ten were dead the 24th, and four had Botrytis on their bodies in a fruiting condition. The others showed a slight mycelial growth, but no spores. The grubs were all dead by the 28th, but only one exhibited the fungus in fruit. Six had no fungus on their bodies, and had probably died from some other cause. Several grubs kept in a stock cage near by died apparently in the same way as those last mentioned, and no fungus appeared on their bodies.

No. 20. October 31. A test-tube culture on agar infected from No. 16. Faint growth in a few spots November 7. Growth slow, barely showing white here and there November 12. November 14, agar now colored red over about two thirds of the surface. No. 15, agar wholly red. November 19, mycelium spreading, but no other change. November 25, red of agar nearly all gone, a portion of the mycelial mass of a creamy yellowish color, and bearing spores.

No. 21. May 25. An infection experiment with Cyclocephala and Lachnosterna larvæ dusted with spores from one of the Fribourg & Hesse cultures received February 19. Fifty larvæ were dusted with Botrytis spores, placed in a breeding-cage on damp sand and covered with blue grass sod, where they were left without further inspection until June 29. On this date three grubs, two pupæ, and eleven imagos were found dead. One dead larva had a slight mycelial growth on it. Dead larvæ removed and placed on damp sand. July 8, one larva had developed on its body a considerable fungous growth which was in a fruiting condition. The experiment immediately following was begun with spores from this grub.

A lot of fifty grubs was kept under similar conditions as a check. Several dead larvæ, pupæ, and imagos were found among them June 29, and were placed on damp sand. No fungus appeared.

No. 22. July 8. A test-tube culture on agar infected with spores of the Botrytis fungus derived from a grub taken from experiment 21. The fungus started promptly, and was visible on the surface of the medium on the 10th, but bacteria appeared in the tubes and the growth became generally impure. The appearance of the characteristic reddish discoloration of the agar July 13, was finally the only evidence of the growth of the *Botrytis tenella* in these tubes.

No. 23. July 13. An infection experiment with lepidopterous larvæ and plant-lice (collected by sweeping clover) dusted with Botrytis spores from one of the imported cultures received February 19. The insects were placed in a jelly-glass with clover leaves for food. Some of the plant-lice and two of the caterpillars had died by the 25th; but no fungus appeared at any time in this cage.

No. 24. October 31. An infection experiment with *Anasa tristis* and Euschistus, dusted with Botrytis spores from the Fribourg & Hesse culture. The spores were rubbed over the spiracles of some and dusted on others. The bugs had begun to die November 12; but no Botrytis appeared at this time or later, although the dampness was sufficient to permit the growth of common blue molds on their bodies.

No. 25. November 17. Test-tube culture on agar infected with spores from the same source as those used in No 24. Experiment continued until November 30, but only a green mold appeared in the tube.

No. 26. March 12. Fruit jar cultures on corn meal and beef broth infected with spores of Sporotrichum from corn-meal cultures 14, 31, and 94 of 1891 series. Eight jars were filled and sterilized as usual, and treated with spores from the above sources. The fungus of the white muscardine started promptly; was in a fruiting condition thirteen days later; and had ripened its spores by April 3. As some of the jars were quite moist inside at this time, the caps were removed and cotton substituted. April 26 the spores were brushed from the surface of the nutrient material in five jars. and placed in a dry jar for future use.

No. 27. March 14. Fruit-jar cultures of Sporotrichum on corn meal and beef broth similar to No. 26, except that the spores came from cultures 14, 32, 47, 50, and 94 of series 1891. Fourteen fruit-jars were prepared and infected. Seven days later, the jars infected with spores from culture No. 14 (June 4, 1891), which had been made more than nine months before, contained a profuse mycelial growth of the white fungus. The fungus failed to develop in five other jars, which were sterilized a second time and again infected with spores from cultures 31 and 94 (1891 series) on the 17th. Six days later there was a fair growth of Sporotrichum on the meal. March 30 a greenish growth appeared in a few jars and somewhat retarded the development of the white fungus. This greenish fungus did not spread, however, after April 6. Sporotrichum spores were very abundant April 4, and were fully developed in some jars two days later. Spores removed from four jars on the 26th, and placed in a dry jar for future experimental purposes.

No. 28. March 30. An experiment to test the possibility of so thoroughly wetting the spores of *Sporotrichum globuliferum* that they might be distributed in a spray. It became also incidentally an experiment on the beginnings of germination of the wetted spores. The fungus spores were taken from corn-meal cultures 26 and 27 and dusted upon the surface of water in a large open-mouthed bottle. The water was then violently forced in and out by means of a syringe. This agitation was twice repeated, and half an hour later the spores were floating on the surface of the water, but so thoroughly wet that the least disturbance caused them to sink. An examination of the spores under a microscope a few hours later showed that they had already begun to grow, many of them having sent forth mycelial sprouts whose length was two or three times the diameter of the spore. On the 31st, growth was much more general and advanced, large numbers of the isolated spores having sent forth threads in two directions, and little clusters of spores bristling with growing hyphæ Four days afterwards, little advance had been made, probably because the nutriment in the spores had been exhausted, while the fluid containing them yielded no nutriment.

No. 29. April 7. An infection experiment with chinch-bugs treated with Sporotrichum spores from corn-meal cultures 26 and 27. Fifty chinch-bugs were placed in water, the surface of which had been previously dusted with fungus spores. The insects were so thorough coated with spores that they had a whitish appearance when removed. They were then put into a pint fruit-jar and supplied with green wheat for food. No conspicuous fungus infection in this case during the entire month of April. On May 2, eight dead bugs covered with Sporotrichum were removed, and several others imbedded in the same fungus were seen the following day. No trace of the disease was seen in the check at any time.

No. 30. April 20. An infection experiment with chinch-bugs treated with Sporotrichum spores from cultures 26 and 27. Fifty chinch-bugs were well dusted with spores and put into a small wooden box, the inside of which had been previously treated with spores, with a supply of food. The box was then placed on damp sand and covered with a box of larger size. A few dead bugs were seen May 1, but no fungus was visible. Twelve days later two bugs covered with mycelium were seen, on which spores had begun to form by the 14th. Other bugs were dead and covered with the fungus on the 20th. All were dead by June 5, but less than two thirds showed any trace of Sporotrichum on their bodies.

No. 31. May 4. An infection experiment with a miscellaneous lot of insects dusted with spores from cultures 26 and 27. The insects were treated with spores, put into a half-gallon fruit-jar, and supplied with food. On May 8 they were transferred to a wooden breeding-cage. All had died by May 12, but no fungus had appeared. May 16 a bumble-bee showed an external growth of Sporotrichum about the head and thorax.

No. 32. May 4. An experiment with larvæ and adult insects (Silphidæ and Dermestidæ) treated with spores from cultures 26 and 27, and placed in a breeding-cage. Eight days later one silphid larva had died and one was covered with Sporotrichum. A few beetles were dead with the same fungus on the 16th. Nearly all were dead on the 28th, and most of them were covered with the fungus of the white muscardine. Fungus spores from some of these beetles were used in the experiment next succeeding.

No. 33. June 20. A contagion experiment with *Ischnodemus falicus* (a bug closely related to the chinch-bug) treated with spores from a dozen beetles taken from the experiment next preceding, and then placed on damp sand under a bell-glass. Half a dozen bugs dead with this fungus were removed June 30, and all were dead by July 8, about one twentieth of them being covered with the fungus. A slender brown spider and a lampyrid beetle accidentally enclosed in the cage were found dead with the same fungus.

A check on this experiment was established at the same time with insects of the same species kept under similar conditions.

June 27 one bug was dead and covered with Sporotricium; otherwise all remained without loss. It is quite likely that this insect became infected from the neighboring experiments.

No. 34. May 10. A farmer's contagion box started by Mr. Marten, on the farm of Mr. John T. Finley, near Tilden, Illinois. The box was prepared according to the Kansas method, stocked with about two hundred live chinch-bugs collected on the Finley farm, and infected with culture material from Nos. 26 and 27. June 15, examined by Mr. Marten and found in good condition; a few bugs dead with Sporotrichum. Mr. Finley had not distributed any of this material in his fields on account of the scarcity of chinch-bugs. The box was examined a second time by Mr. Marten August 11, and found in good condition. Several dead bugs covered with Sporotrichum were seen but no diseased bugs were distributed.

No. 35. May 11. A farmer's contagion box, like No. 34, infected from Nos. 26 and 27. Started by Mr. Marten on farm of Mr. Charles Ferguson, near Odin, Illinois. Owing to a scarcity of chinch-bugs on this farm no use was made of these infected specimens.

No. 36. June 6. An infection experiment upon Cecropia moths. Twenty-four moths reared from cocoons were treated with Sporotrichum from cultures 26 and 27 by rubbing the spores along the spiracles, and were then placed on moist earth in a breeding-cage. June 8 several more moths were dusted with spores from the same source and placed in the cage. Several of the lot first introduced were dead, but showed no trace of Sporotrichum. A Tachina fly had emerged from one. The fungus was seen on the tarsi of a few specimens on the 18th, and several moths examined June 22 had the abdomen filled with a fungus mycelium. Sporotrichum had appeared externally on more of these dead moths by June 30. In the meantime Cecropia larvæ had hatched from eggs laid in the breeding-cage, and July 5 these also began to die, Sporotrichum appearing on their bodies July 8. and ripening by July 11. These larvæ were fed with box-elder leaves.

No. 37. June 20. An infection experiment upon *Ischnodemus falicus* precisely similar to No. 33, except that the fungus spores came from cultures 26 and 27. The insects all died by July 8, and about one tenth of them were covered with Sporotrichum. Two other insects (a Euschistus and a long-horn beetle) accidentally enclosed in the cage were also dead and imbedded in the fungus.

Check the same as that for No. 33.

No. 38. June 20. An unsuccessful infection experiment upon a lot of Diptera collected from flowers, placed on moist sand, treated with spores from Nos. 26 and 27, and covered with a glass cylinder which was closed at the top with gauze. The insects were all dead and partly decayed by July 8, but with no traces of Sporotrichum.

No. 39. June 21. An unsuccessful infection experiment upon *Ischnodemus falicus* dusted with spores from Nos. 26 and 27.

The insects were treated with Sporotrichum spores and placed in a dry fruit-jar, which was then covered with gauze. The insects had all died by June 30 but no fungus appeared.

No. 40. June 21. An infection experiment similar to No. 37. Bugs placed with grass in breeding-cage, and infected by dusting spores on earth and grass. The first fungus-covered specimen was seen July 1, and by July 8 all were dead.

Check the same as that for No. 33.

No. 41. June 28. An infection experiment upon larvæ of *Vanessa antiopa* treated with spores from Nos. 26 and 27. About seventy-five nearly full-grown larvæ collected from willow were placed in a fruit-jar, dusted with Sporotrichum spores, and then transferred to a wooden breeding-cage, the bottom of which was covered with a layer of damp earth and strewn with the food plant. Eight days later all the larvæ had pupated. Most of the butterflies emerged by the 14th, but no fungus appeared. Two larvæ, however, died in the check July 6, and one showed traces of Sporotrichum; otherwise the insects remained without loss.

No. 42. August 15. A contagion experiment with chinch bugs exposed to infection from the Vanessa larva dead with Sporotrichum, taken from the check on the experiment next preceding. Several hundred chinch-bugs were placed in a small wooden box with green corn leaves for food, together with the larva dead with the white fungus. Several dead bugs were seen August 26, some of which were covered with Sporotrichum in a fruiting condition. Many other bugs were dead and imbedded in the same fungus by the 29th.

No. 43. July 5. An unsuccessful infection experiment upon larvæ of *Papilio asterias* treated with spores from cultures 26 and 27. The larvæ were thoroughly dusted with spores and placed in a breeding-cage on damp sand with food plant. Part of the larvæ died but no white fungus appeared in the cage. Many of these caterpillars died of *flacherie* in both check and infected lot. No Sporotrichum seen at any time. Two butterflies appeared in the infected cage and two in the check.

No. 44. July 15. An infection experiment with a lot of miscellaneous insects, mostly grasshoppers, dusted with spores of Sporotrichum from cultures 26 and 27. The insects were kept in a tight wooden box, dampened inside and containing a layer of dirt, with grass for food. The box was then placed on a bench in a cellar. The insects were all dead by August 1, but no fungus of the white muscardine appeared.

No. 45. July 26. An unsuccessful experiment with army worms (larvæ of *Leucania unipuncta*). Several hundred larvæ were dusted with fungus spores from Nos. 26 and 27 and placed in a breeding-cage, with fresh oats and grass for food. The experiment was a total failure so far as the development of Sporotrichum was concerned. The larvæ had all died by August 6; some with *flacherie,* and many others from attacks of parasitic Diptera and Hymenoptera.

No. 46. August 8. An infection experiment on cabbage worms. Several larvæ of *Pieris rapæ* were treated with spores from Nos. 26 and 27, and placed on a cabbage leaf under a bell-glass. All died from the attacks of Micrococcus and parasitic Diptera. No Sporotrichum appeared at any time.

No. 47. August 8. A contagion experiment made with a lot of miscellaneous insects, mostly leaf-hoppers. The insects were placed in a wooden box 12x12x14 inches, and food supplied, together with small pieces (less than half a dram in quantity) of the solid material bearing ripe spores from cultures 26 and 27. The box was then placed on the cellar floor. The insects were all dead by the 26th, and many of them bore a profuse external growth of Sporotrichum, which fruited abundantly a little later.

No. 48. August 15. A contagion experiment with chinch-bugs. Several hundred chinch-bugs were placed in a small wooden box and supplied with corn leaves which had been previously dusted with fungus spores from 26 and 27. The box was then thoroughly moistened inside and placed on damp sand in a shady corner in the insectary. No evidence of disease was detected on the 18th, but three days later two bugs were dead, with an external fungous growth. On the 26th many more were imbedded in Sporotrichum, much of it nearly ripe. August 29, still more were dead. No further record was kept.

No. 49. March 14. Test-tube cultures on corn meal and beef broth infected with spores from cultures 7 and 14 of the series of 1891. Six tubes were prepared and treated with Sporotrichum spores. The fungous growth showed nicely four days later, and three tubes contained an apparently pure growth, while in three others the culture was mixed. Spores were forming on the 22d, and apparently all were ripe on the 28th—fourteen days from the time the culture was begun.

No. 50. April 11. A culture on corn meal saturated with beef broth infected with spores from No. 49. This culture was made with a view to finding a method of growing Sporotrichum in considerable quantity more conveniently than by the ordinary method already described. Two small cheese-cloth sacks were filled with corn meal and soaked in beef broth until the meal was saturated. They were then placed in fruit-jars and sterilized at 100° Cent. for one hour, and treated with Sporotrichum spores from No. 49. The fungus had made a short furry growth four days later, and on the 16th was quite vigorous on a part of the cloth surface. On the 18th almost the whole of the surface was covered with a good mycelial growth, spores had begun to form on the 19th, and a part of those were ripe by the 21st, or ten days after the beginning of the experiment. The growth on this cloth-covered surface was, however, much less profuse and fruitful than that on bare corn-meal batter.

No. 51. May 9. Infection experiment with white grubs (Lachnosterna) collected from ground in the orchard on the University farm, and treated with Sporotrichum spores from culture No. 49. The grubs were placed in a breeding cage similar to that used in No. 19. The experiment was fairly successful, and several dead grubs were removed whose bodies were covered with Sporotrichum, fruiting abundantly. Spores from two of these grubs were used to infect two agar cultures (Nos. 52 and 54), both of which were successful; and these were used, in turn, for inoculating other cultures.

No. 52. July 8. Test-tube cultures on agar infected with Sporotrichum spores from a white grub removed from experiment No. 51. Mycelial growth had begun two days later. Slight traces of bacteria present on the 11th, the white fungus growing freely. Bacteria had disappeared the 14th, and the white muscardine was vigorous. Spore heads were forming the 15th, or seven days after the fungus spores were sown.

No. 53. November 17. Cultures precisely similar to No. 52, and infected with spores from that experiment. Three tubes were prepared, in which the white fungus was growing fairly well three days later. It spread slowly, but in a pure culture, to the 25th, and spores were abundant on the 30th, or thirteen days from the time the agar was infected.

No. 54. July 15. Agar cultures precisely similar to No. 52, being infected with Sporotrichum spores from the same source (No. 51). Mycelial growth visible three days later, and spores ripe in seven days.

No. 55. July 15. Six successful test-tube agar cultures infected with spores from culture No. 54.

No. 56. October 31. A test tube agar culture infected with spores from No. 55. Slight mycelial growth in three days. Spores forming very abundantly November 7, and beginning to ripen on the 14th—fifteen days after the original spores were sown.

No. 57. November 17. An agar culture, infected from the preceding (No. 56) with similar results.

No. 58. May 25. An infection experiment with white grubs (Cyclocephala and Lachnosterna) dusted with spores of *Isaria leprosa.* This infection material came from an agar culture originally made with spores from an earlier agar culture received from Dr. Thaxter March 21. The grubs were treated with spores, placed in a breeding-cage, and covered with blue-grass sod. They were left there undisturbed until June 29, at which time several dead grubs were removed and placed on damp sand The Isaria fungus developed rapidly on their bodies and was in a fruiting condition July 2. The check on this experiment was the same as that used in No. 21.

No. 59. July 8. Test-tube cultures on agar treated with spores of *Isaria leprosa* from a grub out of No. 58. A good growth of mycelium had started July 10, which spread rapidly over the surface of the medium. Spores had begun to form in both tubes the 16th, and were colored as in the original Thaxter tube the 20th. Spores fully ripe the 25th, and easily detached by shaking.

No. 60. July 25. An infection experiment upon chinch-bugs treated with spores of *Isaria leprosa* from agar culture No. 59.

The bugs were enclosed in a tight wooden box on damp sand, and supplied with corn leaves for food. All had died by September 5, and no traces of fungus of any kind were seen at any time.

No. 61. December 13. Test-tube culture on agar infected with Isaria spores from culture 59. Results similar to those of No. 60.

No. 62. July 7. Test-tube agar culture treated with spores of Isaria from the original Thaxter culture of March 21. Pure white mycelial threads covered the surface of the agar by July 11, and spores were very abundant three days later.

No. 63. October 31. Test tube agar culture infected with spores of Isaria from same source as No. 62. The fungus had started freely two day later; had begun to form spores and had assumed a distinct pinkish tinge November 12, and was fruiting abundantly November 14. Spores had the characteristic color of ripeness on the 19th, and were easily detached by shaking.

No. 64. May 9. An experiment intended to test the possibility of a transfer of *Botrytis tenella* from one white grub to another in the earth. For this purpose thirty larvæ of Lachnosterna were placed in a breeding-cage and covered with earth, and with these were buried, separately, five dead grubs covered with a dense growth of Botrytis,bearing spores, from experiment No. 12. Wheat was sown in the cage to furnish natural conditions and to afford food, and a check lot was established and similarly provided for. Seven days thereafter no effect was visible, but one grub was dead in the check. At the end of a fortnight two larvæ had died in the experimental lot, but with no appearance of a fungus mycelium. One month later (June 23) sixteen living larvæ were found in this cage, one had died from *hymenopterous* parasitism, and the eleven remaining were dead, but with no appearance of a fungous growth. Matters remained in substantially this condition until July 5, when one additional dead larva was found, together with two living pupæ. August 26, when the experiment was abandoned, the cage contained eleven adult June beetles (Lachnosterna), one remaining pupa, and a second larva killed by a hymenopterous parasite (*Pelecinus polyturator*). The dead white grubs whose remains were detected in the earth showed no trace of fungous infection, and the check cage was reported by the assistant who conducted the experiment, to be in practically parallel condition.

No. 65. April 19. An agar culture of *Isaria leprosa,* made in the botanical laboratory of the University with spores from the original Thaxter tube. A successful culture.

No. 66. June 3. An agar culture like the four preceding, and infected with spores from No. 65.

No. 67. November 3. Test-tube agar culture treated with Isaria spores from No. 66. A dense white mycelial growth covered about half the nutrient material on the 7th, mycelial threads were of a pinkish tinge the 12th, and spores were forming the 14th, the greater part of which were ripe three days later. The color had in the meantime deepened, and both mycelium and spores were fully colored November 19, where the agar was thin;

but in the lower part of the tube, on the thicker agar, the mycelium was still white and much more dense, and some of it was but just beginning to form its spores.

No. 68. December 16. An infection experiment with pupæ of the "woolly bear" (*Spilosoma virginica*) and other Arctian pupæ. Seven pupæ were treated with Isaria spores from No. 67 by rubbing them over the spiracles and between the segments of the abdomen. They were then placed in a covered jelly-glass. One moth and several hymenopterous parasites emerged, and one dead pupa was found February 10, 1893, with a slight fungous growth on its body.

No. 69. March 22. An agar culture to test the vitality of Sporotrichum spores taken from the original Thaxter culture (No. 7, 1891). No white fungus appeared. A fungus which produced spores of a greenish tinge appeared in the tube, and fruited abundantly March 29.

No. 70. March 24. A second agar culture, like No. 69, and yielding similar results.

No. 71. May 5. Test-tube cultures on agar infected with Sporotrichum spores from chinch-bugs dead with that disease, taken from a stock cage, kept in the insectary, in which the fungus appeared spontaneously. The bugs were originally collected at Litchfield, Illinois, September 23, 1891. Eight test-tubes of agar were infected from this source. The white fungus made a vigorous start, but was soon destroyed by a common mold which appeared May 9. Experiment a failure so far as Sporotrichum was concerned.

No. 72. May 11. Eight test-tube cultures precisely like the foregoing (No. 71), the spores coming from the same source. The white fungus had appeared in all the tubes four days later. Two tubes contained a seemingly pure culture, while in the others a common mold had also grown. These cultures grew slowly because of cool weather, and by May 20 the molds had fruited, and were being suppressed by the Sporotrichum. The latter had produced ripe spores by May 25, and those from the purest of these tubes were used for infecting corn-meal cultures in the experiment immediately following (No. 73).

No. 73. July 7. Fruit-jar cultures on corn meal and beef broth. Fourteen fruit-jars were each supplied with two small sacks of corn-meal thoroughly soaked in beef broth (prepared like No. 50), and sterilized on two successive days for two hours each day, at a temperature varying from 100° to 120° Cent. Spores from agar culture No. 72 were then introduced. The fungus had begun to grow on the medium by the 9th. A slight mold appeared in some of the jars the 11th. Sporotrichum spores were forming the 15th, and were generally ripe three days later, except that excessive moisture retarded the growth in some of the jars.

No. 74. June 20. A contagion experiment with *Ischnodemus falicus*, collected from wild grass. The bugs were placed on damp sand under a bell-glass with a dozen chinch-bugs dead with Sporotrichum, which came originally from the same source as those used in No. 71. Many bugs were dying three days later, and by the 27th one was covered with mycelial threads, some of which were bearing spores. The death rate increased until July 8, at which time all were dead, about half the insects placed in the cage being covered with Sporotrichum, as were several other species (*Anomœa laticlavia, Nodonota tristis, Formica fusca, and Chœtocnema subviridis*), accidentally enclosed. One bug was found dead with the white fungus June 27—almost certainly as a consequence of infection from the neighboring experimental lots.

No. 75. May 6. An infection experiment with plant-lice treated with spores of *Entomophthora aphidis* from chinch-bugs dead with that fungus, received from Dr. Snow in October, 1891. A geranium leaf covered with plant-lice, and a fungus covered bug, were placed in a bottle together and shaken up. Three days later the insects were transferred to a geranium on which lice were abundant. Several died a few days later, but no fungus appeared on any of them.

No. 76. May 17. A test-tube agar culture infected with spores of Sporotrichum from an insect (Euschistus) collected May 10 in a wheat field near Tilden, Illinois. The fungus had begun to grow on the culture medium by the 20th; spores were forming three days later; were apparently ripe by the 30th; and were easily detached by shaking June 4.

No. 77. November 17. A culture on agar infected with spores of Sporotrichum from No. 76. No Sporotrichum appeared, but a greenish mold grew instead, fruiting abundantly by Nov. 22.

No. 78. May 25. A test-tube agar culture of *Botrytis tenella*, started with spores of a culture received from Dr. Thaxter May 21. Thaxter's material originally came from Prof. A. Giard, of France. A slight growth of mycelium had appeared in the tube by May 30, which mostly disappeared, however, by June 6. Spores were forming on the fungus June 10, and by June 14 were ripe enough to shake off.

No. 79. July 7 Two agar cultures like No. 78, being infected with Botrytis spores from the same source. Four days later mycelial tufts were visible on the nutrient material, and the agar was slightly discolored, being of a brownish tinge. July 12 one tube contained a good growth of fungus, and the agar was slightly tinged with red. The growth in the other tube was not quite so vigorous. July 14 the growth was very strong, and the agar had turned a reddish tint like that in Nos. 4–10. By the 16th this reddish tinge was fading, and spore heads were forming on the surface. Mature spores were abundant by the 22d, and the red color in the agar had then almost disappeared.

No. 80. June 28. A contagion experiment with caterpillars of *Vanessa antiopa.* Several Datana larvæ dead with Sporotrichum had been left in the breeding-cage described under No. 51, 1891. It must be borne in mind that these Datana larvæ had been in this cage about eleven months. On June 28, 1892, they were well covered with spores whose vitality it was desired to test. Several larvæ of *Vanessa antiopa* collected from willow were placed in the cage. Five days later two had died and one had begun to pupate. By July 4, all of the caterpillars but three were attached to the top of the cage. Twenty-seven had died by the following day, and only nine had succeeded in pupating. An examination of one dead larva showed the presence of mycelial threads in its body cavity. By July 11 the white fungus had appeared externally on twenty-eight larvæ, and spores were forming on several. Only one insect succeeded in maturing, and this emerged July 14.

No. 81. July 19. A farmer's contagion box, started by Mr. Marten on the farm of Mr. F. O. Vantuyle, near Manchester, Illinois. The box was prepared as in No. 34, spores of Sporotrichum being supplied from our laboratory. The box was examined every other day, and supplied with live insects and fresh food when needed. About one week later a quantity of bugs, both dead and alive, were removed and placed in two corn fields, behind leaf sheaths, where chinch-bugs were most numerous. The box, and the fields in which the diseased bugs had been distributed, were examined by Mr. Marten August 12. The box was in good condition, and contained many fungus-covered chinch-bugs. One chinch-bug dead with Sporotrichum was found under a clod in one of the fields where the fungus had been scattered, but aside from this no traces of muscardine disease could be found in the neighborhood at that time.

No. 82. July 20. Two test-tube agar cultures sown with Sporotrichum spores from adult dead chinch-bugs taken from a barley field near Forreston, Illinois, June 20. Both cultures were successful, and produced good growths of the white fungus.

No. 83. August 15. An infection experiment with chinch-bugs collected at Forreston August 18. Several hundred bugs, pupæ and adults, were placed in a test tube which contained Sporotrichum in a fruiting condition, growing on agar agar, and shaken until thoroughly covered with spores. The insects were then placed in two small wooden boxes and supplied with food, and the boxes were set on damp sand in the insectary. Several had died by August 21, but no external fungous growth was seen on their bodies. By the 26th, many in both boxes had died and were imbedded in fruiting Sporotrichum, and by the 29th, still others. With this the record ceases.

No. 84. November 15. An agar culture sown with spores from a beetle dead with Sporotrichum, found near Urbana, Illinois, November 8. A few isolated spots of white mycelial threads were seen November 18. Bacteria also present in the tube at this time. A small tuft of this fungus transferred to a second tube of agar November 20. Growth very slow, but a dense mycelial cluster had formed by the 30th. Spores had begun to appear December 1, and the mycelial threads almost completely filled the lower part of the tube. Spores were abundant December 10, but had ripened very slowly.

No. 85. April 19. Infection experiment on white grubs with spores from agar culture made by Prof. Burrill. This culture was itself derived immediately from the Thaxter tube already mentioned. Twenty grubs were dusted April 19 with spores from this growth and placed in an earthen vessel, which was filled with leaf mold and sunk in the earth. Grubs died in this lot April 23, 25, and 27, most of them becoming firm to the touch and of a dusky brownish hue. The record shows the death of thirteen of this experimental lot up to May 20, at which time ants invaded the cage and the experiment was discontinued. Five dead specimens, transferred to damp sand May 30, simply decayed without visible fungous growth. Only two of the lot, in fact, formed a mycelium, and none matured spores.

No. 86. November 25. Agar cultures in test-tubes infected from No. 20. November 29, culture growing, but agar not yet tinted. December 1, growing slowly, with red discoloration of the medium. December 5, spores formed. December 8, spores becoming yellowish and beginning to ripen. December 12, spores abundant and seemingly ripe.

THE YEAR 1893.

During 1893, the year of the great Columbian Exposition at Chicago, the office force was so largely engaged in the preparation, installation, and supervision of the exhibit required of us by law, that comparatively little could be done with experimental work, and this little only during the latter part of the season.

The experiments with insect diseases were eighteen in number, the first made April 6—an infection experiment with *Isaria leprosa*, applied to pupæ of the tomato worm (Protoparce), the result of which served to support the conclusions drawn from the work of the previous year with regard to the promise of this fungus species. The remaining experiments were all made with *Sporotrichum globuliferum*, and all but one upon the chinch-bug.

A general contagion box was established July 1 (experiment 2) and kept in operation until September 6, its product being distributed to correspondents of the office for use in the field.

Nos. 3-9 of the list for this year are small laboratory infection experiments, all of which were carried far enough to indicate successful inoculation with the fungus, when the contents of the boxes were united with those of the larger box just mentioned.

No. 10 was a laboratory contagion experiment, the spores for which were derived from dead chinch-bugs kindly sent me by Professor Snow, of Kansas; and Nos. 12–18 were field infection experiments in Southern Illinois, only one of which (18) gave the slightest evidence of a useful result. The single plant-louse contagion experiment (No. 11) was unsuccessful.

DETAILED DESCRIPTION OF EXPERIMENTS—1893.

No. 1. April 6. An infection experiment upon Sphinx pupæ with spores of *Isaria leprosa* from agar culture of 1892, not more definitely described. Two pupæ brought in from the field, apparently of the tomato Sphinx (Protoparce), were treated by rubbing ripe spores of this fungus into their spiracles and over the intersegmental spaces. They were then placed under cover on damp sand in the insectary. April 10, apparently dead; although the bodies are flexible, they do not respond to irritation. April 14, bodies quite stiff. April 16, interior of bodies of these pupæ filled with fungus mycelium. April 18, white mycelium growing from cuts in pupæ. April 20, this mycelium growing in a thick tuft, and mere points of mycelium appearing also through the spiracles. April 23, mycelial tufts fruiting; others commencing to penetrate the chitinous pupal covering. April 27, spores developed on the older mycelial tufts, and becoming faintly colored on the oldest. General penetration of the chitinous crust quite marked, especially beneath the thorax and the abdominal segments. May 1, mycelium breaking through the surface everywhere; spores ripe and fully colored on the older growths. May 10, spores generally ripe. May 24, mycelium has penetrated a piece of thin card board on which the specimens were placed.

No. 2. July 1. A general contagion box for the multiplication of Sporotrichum and the distribution of infected bugs to farmers. A quantity of chinch-bugs from Xenia, Illinois, inoculated July 20 with spores of *Sporotrichum globuliferum* from a recent agar culture, and placed in a cellar, in a wooden box, with grain and corn for food. July 22, additional chinch-bugs from Southern Illinois placed in the box; July 24, still others from Ashley and Xenia, in Southern Illinois; and July 26, again, from the southern part of the State. July 28, a few bugs dead with Sporotrichum. August 1, box thoroughly overhauled; about one fifth of the bugs dead, a few of them covered with Sporotrichum and a few with *Entomophthora aphidis.* August 4, fresh food put in box. No noticeable increase of fungous infection. August 9, number of dead bugs not increased. August 10, transferred to a new box, together with seven smaller collections (Nos. 3–9) received from various parts of the State, and which had been infected with artificial cultures of Sporotrichum July 28 and 31. A large quantity of bugs collected from the field at Odin, Illinois, also placed in the box, most of them young. A quantity of dead bugs with external growth of Sporotrichum taken out and prepared for shipment. August 12, a few more dead, with fresh growth of fungus. August 17, Sporotrichum increasing very slowly. August 20, development of fungus still very slow. Box removed from cellar to shaded place on the sand floor of the insectary. August 22, several bugs noticed with fresh growth of Sporotrichum, and August 24, still others. August 29 and 31, a gradual increase of fungus-covered bugs. September 5, box in excellent condition; many bugs dead with fungus, but at least as many without. September 6, box cleaned up, and enough dead and fungus-covered bugs taken out to supply eighteen correspondents.

No. 3. July 28. Chinch-bugs dusted with spores of cultivated Sporotrichum, and placed with green corn in a wooden box. August 4, four bugs dead with surface fungous growth. August 9, no more dead. August 10, transferred to No. 2.

No. 4. July 28. Chinch-bugs dusted with spores of cultivated Sporotrichum and placed with green corn in a glass cylinder on wet sand, the top of the cylinder being covered with cheese cloth August 10, only three bugs found with external fungous growth. Transferred to No. 2.

No. 5. July 28. Chinch-bugs dusted with spores of cultivated Sporotrichum and placed with green corn in a glass cylinder on wet sand, the top of the cylinder being covered with cheese cloth. August 9, two bugs dead with fungus found behind the leaf sheath. August 10, transferred to No. 2.

No. 6. July 28. Chinch-bugs dusted with spores of cultivated Sporotrichum and placed with green corn in a glass cylinder on wet sand, the top of the cylinder being covered with cheese cloth. August 4, no sign of disease. August 9, two bugs dead with Sporotrichum behind leaf sheath of corn. August 10, transferred to No. 2.

No. 7. July 28. Chinch-bugs dusted with spores of cultivated Sporotrichum and placed with green corn in a glass cylinder on wet sand, the top of the cylinder being covered with cheese cloth. August 4, no disease. August 9, one bug dead with Sporotrichum behind leaf sheath of corn. August 10, transferred to No. 2.

No. 8. July 31. Chinch-bugs infected with spores of cultivated *Sporotrichum globuliferum* and placed in a small wooden box with corn stalks for food. August 2, one bug dead with external growth of mycelium. August 4, a few more showing Sporotrichum. August 9, in about the same condition as No. 10. August 10, no apparent increase in number of dead bugs. Contents of box transferred to No. 2.

No. 9. July 31. Chinch-bugs infected with spores of cultivated *Sporotrichum globuliferum* and placed in small wooden box with corn stalks for food. August 2, a few bugs dead with external growth of white mycelium. August 4, no apparent change. August 9, little, if any, increase in number of dead bugs Contents of box transferred to No. 2.

No. 10. August 2. Contagion experiment with chinch-bugs confined with Kansas specimens. Bugs from Thomson, Illinois, placed in small wooden box with green corn for food, and about two dozen bugs dead with *Sporotrichum globuliferum* from Dr. Snow, of Kansas, also placed in the box. August 4, no visible fungous growth. August 9, three bugs dead, with white mycelium on them. August 12, a few more dead, with external fungous growth. August 16, about half the bugs in this box are dead, but less than a fourth of these exhibit any external fungous growth; on some, however, the growth is very luxuriant. August 18, no more bugs dead.

No. 11. August 2. Contagion experiment on plant-lice confined with chinch-bugs dead with white muscardine (Sporotrichum). Small pieces of corn stalk bearing corn leaf lice (*Aphis maidis*) and an undetermined small white species were put into a wooden box, and kept on the damp sand floor of the insectary with chinch-bugs dead and covered with fruiting growth of *Sporotrichum globuliferum*. August 8, plant-lice multiplying in the box. August 12, several of the smaller species dead, their color changed to brick-red. August 16, still more dead and discolored lice. All these red specimens killed by an Entomophthora, afterwards determined as *Entomophthora fresenii*. August 20, plant-lice dying slowly with Entomophthora, many of them anchored to the corn stalk by simple threads. Young as likely to suffer as the old. No appearance of Sporotrichum in this cage.

It may be noted in passing that this same Entomophthora was found September 4 infesting this plant-louse species on roots of *Cyperus strigosus* growing in a trench in the insectary.

No. 12. August 7. A field experiment with cultivated *Sporotrichum globuliferum*. Spores of this fungus from a laboratory culture were dusted by Mr. Marten over a cluster of chinch-bugs in leaves and behind sheaths of corn on the farm of Mr. Pontus, near Odin, Illinois. September 7, traces of fungus material introduced into this field were still visible on some of the stalks. Careful examination by Mr. Marten of the treated stalks and of many others in the vicinity, failed to show a single dead bug, and indeed not one was found on the entire farm. Mr. Charles Ferguson, who assisted in the original treatment of this field, says that he examined it, after rains, August 10 and 24, but found no dead bugs.

No. 13. August 7. Field infection experiment like No. 14, on the farm of Mr. Charles Ferguson, near Odin. Spores dusted by Mr. Marten on bugs clustered behind leaf sheaths of corn. Bugs nearly all young. August 10 a slight rain, and August 24 a heavy one, the latter wetting ground to a depth of about three inches, which was soon dried out, however, by the hot sun. After each of these rains the field was examined by Mr. Ferguson, but no appearance of fungous infection was detected. September 7, visited by Mr. Marten, who found no dead bugs on farm.

No. 14. August 7. Field infection experiment with chinch-bugs on the farm of Dr. E. E. Fyke, near Odin, Illinois. Two badly infested hills in corn field dusted with cultivated spores of Sporotrichum; and in another part of the field, where young bugs were excessively abundant on corn and crab-grass, seven hills were treated by dusting with spores the bugs behind the leaf sheaths of the corn. Bugs mostly young, not having reached the third moult. Drouth severe, and damaging the crop. Field examined carefully by Dr. Fyke after rains, August 10 and 24, but no appearance of disease. September 7, visited by Mr. Marten. Some of the hills retained the material placed on them a month before, but there were no dead bugs in or about any of them. Many hills in the vicinity were examined by pulling down leaf sheaths, turning over clods, pulling up grass and weeds, and searching all places of concealment, but quite without success. Bugs everywhere as abundant as at the preceding visit, August 7.

No. 15. August 7. Field infection experiment on farm of Mr. Arrowsmith, near Odin, Illinois. Bugs behind sheaths of corn dusted with spores from artificial culture on corn meal. September 7, slight traces of original infection still visible about some of the treated stalks. Thorough search for dead bugs made everywhere in the vicinity, but wholly without success. Chinch-bugs as abundant in this field as when it was first visited.

No. 16. August 8. Field infection experiment on farm of Mr. Thomas, near Odin, Illinois. Bugs behind sheaths of corn dusted with spores from artificial culture on corn meal. Spores were freely used on a number of hills marked by cutting the tassels. September 8, corn treated August 8 has been cut and shocked. No dead bugs could be found in the field.

No. 17. August 8. Field infection experiment on farm of Mr. John Bartle. Spores of cultivated Sporotrichum dusted on young bugs (with a few old ones intermingled) behind leaf sheaths of several hills of corn in different parts of a thirty-five acre field. Mr. Bartle and his oldest son closely scanned the treated hills from time to time, and only once—two days after infection and following upon a light shower of rain—were dead bugs noticed. At that time two dead specimens covered with fungus are said to have been seen in the midst of the cultivated material placed upon the stalk September 8. Although several of the hills treated August 8 yet retained traces of the cultivated infection material, not a single dead or diseased bug could be found anywhere upon this farm after prolonged search extending through a considerable part of the day.

No. 18. August 15. A farmer's field infection experiment; material from my laboratory. As this is the only possibly successful field experiment of the season, it may well be reported in some detail.

A vial of spores of *Sporotrichum globuliferum* from a corn-meal culture was sent on the above date to Mr. C——, a farmer living three and a half miles from Xenia, in Clay county, with the following letter of advice and direction:

"I send you by this mail a vial of spores of *Sporotrichum globuliferum,* the chinch-bug fungus with which we are again experimenting this season. Our method of applying it is substantially as follows:

"Place the infected material in a tight wooden box—say 18x20 inches—having a layer of leaves and stalks of corn placed in the bottom, wetting freely the sides and bottom of the box. Then introduce live chinch-bugs—the more the better, a quart would not be too many—and set the box in a shady place,—a cellar does nicely,—renewing the food occasionally, and each time wetting the inside of the box. In a few days, if the experiment succeeds, the bugs will begin to die and become covered with a white mold. Live bugs are supposed to become infected within forty-eight hours of the time of placing in the infection box. They may then be liberated in the fields. The disease will be more likely to spread if introduced into the field during or after a rain.

"By leaving some of the diseased bugs in the box and introducing fresh lots of live bugs from time to time, a supply of the material may be kept throughout the season.

"Do not place too much reliance on this as yet uncertain method, but use other measures of defence as noted in my article recently sent you, copies of which are still available."

September 13, this correspondent wrote: "I am pleased to inform you that your chinch-bug disease is a decided success. I used bugs as directed, and those on my farm are dying off rapidly. How can I save bugs for spring use?"

September 29, this place was visited by my assistant Mr. Marten, who learned that the spores received from us were put into a cigar box with chinch-bugs and leaves of oak and corn. The box was wet when stocked, and, subsequently, every other day while in use. The bugs began to die, according to Mr. C.'s statement, in a day or two, and were scattered in the field about August 20,—five days, that is, after the receipt of the material,—being placed behind the sheaths of the leaves of the corn. There was a slight rain on this date, barely enough to lay the dust; the weather was showery for two or three days following; and on the 24th there was considerable rain, enough to make the roads muddy. In two or three days after the infection of the field dead bugs were numerous behind leaf sheaths, but more abundant on the upper side of the base of the leaf in the groove over the midrib. September 29, at the time of Mr. Marten's visit, dead bugs could be found in all parts of this field of twenty-three acres, but were most numerous where the infection material had been distributed. Unfortunately, however, for the conclusiveness of this report, a vial containing several hundred dead bugs, mostly pupæ and adults, collected by Mr. C—— about September 20, exhibited no evidence whatever of the presence of Sporotrichum, although kept after receipt by us in a situation to favor the development of molds. Many of them are covered with a white fungous growth, but it is a Penicillium not to be confounded on the most casual microscopic examination with the Sporotrichum of the white muscardine. Specimens obtained by Mr. Marten in this field September 29 were in the same condition, and evidence of success with this infection experiment is consequently incomplete. The report of the owner himself is somewhat discredited by the fact that at the date of Mr. Marten's visit he confused cast skins of pupæ with dead bugs.

THE YEAR 1894.

The history of chinch-bug injury in Illinois is substantially that of a succession of waves of increase which slowly rise to a highest point and then rapidly fall away to insignificance, the rise of the wave usually occupying from three to five years or more, and its recession commonly requiring only one or two. Such a period of increase began here in 1890 and apparently reached its culmination in 1894, when it covered a large part of this State from the Ohio River to the northern tier of counties. It also extended beyond our borders into Missouri, Kansas, and southern Iowa. In Illinois it was most injurious this year (1) in the southern and south-central part of the State, (2) in the western-central counties, and (3) in a few counties near the northern boundary—being practically harmless, or nearly so, only in the eastern part of central and north-central Illinois.

Complaints of serious injury and appeals for aid were received at this office during the year from six hundred and ten* towns in seventy-six counties—a number not previously equaled since 1887. The greater part of these appeals took the form of applications for material with which to introduce the contagious insect diseases into infested fields. While the results of our previous experimental work with the principal fungous disease of the chinch-bug were not favorable to the idea that it would be found to have any considerable value as a means of arresting injury by the chinch-bug where conditions were particularly favorable to the multiplication and maintenance of that insect, I was nevertheless induced to undertake to supply this demand, largely by the following considerations:

Notwithstanding our previous experience, I was not yet prepared to say positively that the contagious-disease method if persistently followed up would not take effect in very many cases even under ordinary circumstances; and as long as there was even an appreciable chance that the farmers might thus save any considerable part of their crops this season by our aid it seemed to me that they were entitled to the benefit of the doubt in favor of this procedure, especially as the expense of a general distribution would be at most a trifle compared with the great interests at stake.

The general credit which this method had received through the agricultural papers and the daily press, as well as through several state official publications, and the firm belief which very many of our farmers already had in it, made it seem very likely that nothing would satisfy them except a chance to try it.

I was fairly well assured, as a result of our own field observations and laboratory experiments, that under favorable weather conditions it might do an immense service to those parts of the State threatened with the destruction of wheat and corn; and as we could not foresee the weather of the season, I thought it incumbent on me to take measures to derive the greatest possible advantage from weather favorable to the spread of the disease, if such weather should follow.

The demand for contagion material became so great by June 1 that it was evident that I should no longer be able to meet it from current appropriations at my disposal and with the aid of my usual corps of assistants. I consequently suggested, early in June, to the authorites of the State Agricultural Experiment Station at Urbana, the idea of providing for more elaborate experiments in the field, and of supplying a limited amount of tested infection material for trial by farmers themselves. This plan of experimentation and distribution was very promptly taken up and favorably considered by the executive committee of the Station Board, and I consequently engaged the necessary assistants, enlarged our facilities, and published a general notice to those interested of my willingness to receive live chinch-bugs and to return infected ones in their place. This offer was most eagerly accepted by a large number of farmers, and we were presently very

*In Bulletin 5 from the State Entomologist's office this number was incorrectly given as five hundred.

nearly overwhelmed—as were also the local express offices and the post-office—by packages of chinch-bugs arriving from all parts of the State, and in all imaginable conditions.

Notwithstanding the great enlargement of our facilities, and the continuous expert attention which the whole subject received, especially from Mr. John Marten, who has had principal charge of our disease experiments for four years, the contagion did not spread rapidly enough in our boxes to make it possible to meet at once more than a small percentage of the demand. I found later that a part of this slow development was due to a difficulty which seems not to have been previously noticed by any one here or elsewhere; namely, the appearance in our contagion boxes of swarms of minute mites which fed upon the fungus as fast as it was developed.

Next, observing that large numbers of the thirteen-year locust (*Cicada tredecim*), a brood of which was rapidly disappearing, had died with this disease, and bore a profuse growth of the characteristic muscardine fungus in excellent condition, I had a large quantity of them collected, and used these dead locusts for distribution, accompanied in each case by chinch-bugs which had been previously exposed to the infection.

Finally, having ascertained that the cultivated fungus grown upon a mixture of corn meal and beef broth was apparently as effective for the destruction of chinch-bugs as that obtained from the insects themselves, I had a large quantity grown artificially on this material, and used this also for distribution.

By these methods I succeeded, by about the 20th of July, in supplying all who had sent requests up to the 10th of that month—a little over two thousand for the season. As I had issued a second bulletin June 30, giving notice that it would be impossible to continue the distribution beyond July 10, I considered the obligations I had assumed thus fulfilled, and this work was brought practically to an end.

Each lot of chinch-bugs, living and dead, was accompanied by the following circular of directions for their utilization, and of caution against hasty observation and inference:

"Dear Sir: I send you by this mail chinch-bugs which have been successfully exposed to the white fungus disease of that insect, and are in a condition to convey it to others.

"To propagate this disease in your field, make a tight shallow wooden box, say 24x36x6 inches, and place in it a layer of dirt half an inch deep, free from leaves or other rubbish. Moisten this dirt without making it muddy, and then put in a thin layer of green wheat or corn. Scatter the dead chinch-bugs sent you over the bottom of the box, and shut up with them a quantity of live bugs from the field—as many as can well move about in the box without being anywhere more than one layer deep. Fasten the cover down tight, so that nothing can escape, and set the box where it will be protected from sun and wind. A cellar or a basement room is to be preferred.

"Open the box daily and moisten its sides and contents (without making them muddy) when they begin to get dry, and also change the food as that in the box becomes yellow. When it is seen that the white moldy bugs are becoming more numerous, probably in about three or four days, take a part of the bugs, dead and alive, out of the box, putting in fresh live ones to take their places, and close the box as before.

"Those taken out should then be scattered through the infested field where the bugs are thickest—at the bases of the leaves in the corn-fields, around the lower ends of the stalks, and the like. Make this distribution, by preference, in the evening, when the dew is on, or, still better, just after a rain, and repeat, if dry weather follows. Continue these collections and distributions as above through the whole season, making certain each time chinch-bugs are taken out that white ones are left in the box; and when winter comes put all the dead bugs remaining into pill boxes for use the following year.

"Those wishing to form an independent judgment of the practical value of this method of dealing with chinch-bugs should take into account the following facts:

"1. The white fungus causing insect disease requires moisture for its full development, and especially for the formation of the minute 'spores' by whose dispersal the disease is conveyed from one insect to another. In times of severe drought it propagates slowly or not at all.

"2. It takes effect on a weakened insect more readily than on one in full vigor; on the full grown chinch-bug more easily than on the young; and hence most easily of all on spent adults which have already laid their eggs and are about to perish by the natural termination of their life period.

"3. It is a native disease of the chinch-bug and never dies out entirely, but is likely to appear spontaneously over a large extent of country when conditions favorable to its development are long maintained.

"4. Two generations of the chinch-bug appear each year, and when each of these generations matures, the adult bugs commonly take wing and scatter, thus disappearing largely from fields or parts of fields heavily infested by them. Such dispersal has often been mistaken for a destruction of chinch-bugs by disease. One generation matures shortly after wheat harvest and the other in late summer and in the fall.

"5. The chinch-bug sheds its skin four times while growing, and the empty skins left by it are often mistaken for dead bugs—a mistake which sometimes has led to a false conclusion as to the effect of these infection experiments. The cast skins never bear wings, as the insect does not moult after its wings are formed. They may be further readily distinguished from the dead bugs by the fact that when pressed between the thumb-nails they are readily seen to be shells without contents.

"To judge intelligently of the effect of any attempt to introduce disease, the observer should examine very carefully, in advance, the field in which the experiment is to be tried, and adjacent fields as well, to see whether bugs dead with the white fungus may not already be present. If the disease appears at the point where the infected chinch-bugs are placed, he should repeat this general examination, and make sure that the disease may not have occurred spontaneously and without special reference to his experimental introduction of it. He should also notice whether young bugs (those without wings) are attacked by it, as, if they are not, it is quite likely it is only carrying away those about to die of old age. On the other hand, it should be remembered that these especially susceptible adult bugs may afford the best means of securing a general dissemination of the fungus in the fields, where it may lie dormant for a considerable time, ready to spring into sudden activity when favorable weather conditions appear.

"Advantage should be taken of every considerable shower, and especially of every long rain, to scatter the diseased bugs, and all fields under observation should be thoroughly inspected some two or three days thereafter."

I was also careful in every published statement or written communication on the subject to warn all against reliance upon this method to the neglect of other preventive or destructive measures, and emphasized in every way its purely experimental character.

In the meantime, experiments, carefully planned and closely followed up, were made in the field through Mr. Marten and Mr. Johnson, both assistants of the office, by the distribution, in wheat and corn fields, of fungus cultures and of chinch-bugs dead with disease and bearing the characteristic fungus in a fruiting condition. One series of such experiments was made on the University Experiment Station farm, at Urbana, and others were set on foot at several points in Southern Illinois, each being followed up by repeated visits made to ascertain the result.

The opportunity was improved during these visits to examine also several experiments made by farmers of our acquaintance with material obtained from the office under such conditions and management as to give them positive value.

Additional laboratory experiments directed to special ends were carried on during some weeks by the aid of Miss Nettie Ayers, then an assistant in the bacteriological laboratory of the University of Illinois. Artificial cultures, under varying conditions, of the Sporotrichum characteristic of the chinch-bug disease were made by Miss Ayers, and the results of such cultures were tested upon chinch-bugs, living and dead, upon cabbage worms both living and dead, and upon a variety of other insects, these experiments being so managed that the conditions under which they were made were precisely subject to our control.

In addition to these various experiments with the contagion method, I made at Urbana this summer a thorough test of certain measures for the arrest and destruction of chinch-bugs as they moved from wheat to corn in early June and July.

The entire series, for 1894, of these experimental studies in the laboratory and in the field are here reported, whether made under the immediate auspices of the Agricultural Experiment Station, or as a part of the regular work of the State Laboratory of Natural History.

GENERAL DISCUSSION OF RESULTS.

The more important results of the season's experiments which have an economic value may be briefly summarized in the following terms:

1. The white muscardine will not spread among vigorous chinch-bugs in the field in very dry weather to an extent to give this disease any practical value as a means of promptly arresting serious chinch-bug injury under such conditions. (See Nos. 55 to 58, and 61, 62, 77, etc.) On the contrary, even when it has appeared spontaneously, or as a result of artificial measures for its introduction, it may be completely arrested by dry weather, remaining in abeyance at least until the weather changes. (See No. 53, June 5 and June 20; No. 55, June 7, June 19, and August 8; No. 57, concluding discussion; and Nos. 60, 63, 69, etc.)

2. It is most likely to "catch" in low spots, where the soil is kept somewhat moist by dense vegetation, a mat of fallen herbage, or the like. Shocks of corn, especially when the crop is cut early, furnish excellent places for the development of this disease. (See No. 55, June 20; No. 57, September 18, 19, and 28; and Nos. 76 and 77.) Indeed, the presence in any field, of spots especially favorable to the growth of the Sporotrichum infection seemed, ac-

cording to our observations, to have much more to do with the appearance and spread of the white muscardine among chinch-bugs than even the most persistent distribution of dead or infected specimens in the absence of such natural culture beds—a fact which contains the suggestion of a new method for the propagation and dissemination of this disease. It will be well worth while, consequently, to try the effect of excessive moisture and an inviting shelter on here and there a spot in an infested field, such as might be afforded by an overgrowth of small grain produced by heavy fertilization, or by tramping down a few hills of corn, or by the early cutting and shocking of some small part of the crop. If no spontaneous development of muscardine were to follow, such spots would at any rate be excellent places to start a field infection.

3. If decidedly wet weather follows upon its introduction, even after an interval of several weeks, it is likely to start up and take visible effect; but continuous rains, depressing the vital energies of the insect, seem commonly requisite to its efficient action. (See Nos. 55 to 58, 77, etc.)

4. It is always so generally prevalent, in a more or less obscure condition, among chinch-bugs or other insects in Illinois, both north and south, that it is very like to appear and spread, as if spontaneously, whenever conditions favorable to its development long prevail, whether it has been purposely introduced or not. (See especially No. 76.)

5. The time elapsing between the establishment of such favorable conditions and the full development of the disease among the chinch-bugs of any locality, may possibly be shortened if the infection has previously been introduced by artificial means; but our own experiments, it must be confessed, do not lend any material support to this supposition. (See No. 57, concluding discussion.)

6. Whatever weakens the insect favors its spread, as a rule. It is consequently much more likely to attack adults than young, especially spent males, and females which have laid their eggs and are soon to die of old age; but it nevertheless kills young of all ages. From the record of our large contagion boxes (Nos. 68–71) it appears that after the establishment in my laboratory, July 1, of a special reception box into which all insects sent in by mail or express were put as received, the development of the fungus in the contagion boxes was much less rapid than before. The reception box was so managed that not only were all dead bugs excluded from the contagion boxes, but only the more vigorous of those remaining alive at the time of their arrival were transferred. The apparent effect of this elimination of weakened insects was greatly to diminish the number which succumbed to the muscardine infection.

In agreement with the above, we have noticed that the fall generation of adults is less subject to it, other things being equal, than the generation which matures in midsummer. As this fall brood is to live over winter before laying its eggs, it contains no worn-out adults.

7. The fungus producing this disease will start rarely, if at all, on dead chinch-bugs, if we may judge from the results of several experiments made this summer. (See Nos. 37–40 and Nos. 46–47.) Wherever a dead chinch-bug shows the fungus in the field, it is therefore probable that it was infected when alive. Some doubt is thrown upon this conclusion, however, by the fact that upon dead soft-bodied insects, like cabbage worms, the Sporotrichum grew as promptly and luxuriantly as upon the insects infected while alive. (See Nos. 21–27 and 41.)

8. The resistant power of healthy chinch-bugs exposed to infection is well shown by the fact that thousands of bugs, young and old, have commonly lived for many days, and even for several weeks, moulting, maturing, copulating, and laying their eggs, when shut up in contagion boxes which had been heavily stocked with fungus spores from dead insects, and had been made in every way as favorable as possible to the development of the disease. The percentage of those that would succumb, from day to day, was often ridiculously small. (See Nos. 63–71). On the other hand, it is probable that the heavy pressure upon the office for a supply of infected chinch-bugs frequently induced the too early and complete removal of the bugs from such boxes, thus retarding the development of the fungus among the imprisoned insects.

9. The growth of the fungus in such boxes is sometimes checked and the whole experiment brought to a standstill by the appearance in the boxes of minute mites (apparently brought in with the food supplied to the bugs), which multiply in the boxes and greedily devour the fungus of white muscardine as fast as it grows. (See No. 68, July 31, August 9, and 22; No. 69, July 30 and August 3; No. 70, July 30 and 31 and August 2; and No. 71, July 30.)

These mites were repeatedly noticed by us in July, but were not suspected of an injurious influence on our operations until July 30, when experiments demonstrated that they were diligently feeding on the growing Sporotrichum. Confined with a fungus-covered chinch-bug July 30 at 3 p. m., they had completely cleared it off by the next morning. Another lot, placed under a glass with four such bugs at 9 a. m., had eaten up the last vestige of the fungus by 4:30 p. m. Similar trials showed that they would clear away, with equal readiness, the fungous growth from a culture on corn-meal batter. Prolonged search of the earth outside, made where the supply for our contagion boxes was obtained, and a similar search of the sources of the food supply of the imprisoned chinch-bugs, gave us no hint of the origin of the mites. The same mite species was noticed August 7 in the contagion box of a farmer near Tonti, in Southern Illinois, and it seems likely that these mites came in with the chinch-bugs sent us from the field.

10. Comparative experiments with fungus spores from diseased chinch-bugs, and with those derived from artificial cultures on corn meal moistened with beef broth, show that the latter are nearly, if not quite, as efficient agents of infection as the former. We used this year only cultivated spores two or three removes from

the growth on the insect, and consequently are not prepared to say that continued cultivation on an inanimate medium might not finally diminish the virulence of the fungus parasite; but, on the other hand, we have no very good reason to suppose that this will prove to be the case; and I have no doubt that by a properly guarded procedure these artificial cultures, which can easily be made in almost unlimited quantity, may be utilized for a dissemination of the spores of these insect diseases with great advantage in convenience, expedition, and economy of operation. (Compare Nos. 3, 4, and 5 with No. 54; also, No. 71 with No. 70, up to July 6.)

11. The history of experiment No. 1 and its derivatives shows beyond question the possibility of doing excellent work on chinch-bugs with fungus of this disease derived from other insect species. It is probable that many cases of its apparently spontaneous appearance among chinch-bugs are to be traced to such sources of infection. It was upon this ground that fragments of thirteen-year locusts profusely covered with Sporotrichum were distributed this summer, together with chinch-bugs previously exposed to infection, for experimental use by farmers.

12. A comparison of the infection experiments made on chinch-bugs with those made on cabbage worms (see subsequent list) shows clearly the very much greater susceptibility of the latter to Sporotrichum attack—a fact due possibly to their thinner skin and more juicy substance. Living and dead cabbage worms were infected with equal readiness if the air was kept moist. The spores started quickly on any part of the body, the growing hyphæ penetrating the skin in one place seemingly as freely as in another. An external development of the fungus commonly became noticeable on the second day, as in artificial cultures. Cabbage worms were frequently, but not invariably, turned a dull red color by the growth of the Sporotrichum. In one experiment, which differed from the others by the omission of the layer of moist sand on the bottom of the dish in which the larvæ were confined, this raspberry color was the only external evidence of successful infection with the Sporotrichum, no external growth appearing—a fact probably to be attributed to the comparative dryness of the air.

13. This is the place to make mention of certain experiments with the infection of insects in the laboratory which resulted in unusual developments of *Sporotrichum globuliferum*, illustrated by figures accompanying this report (Plate VII.) With the exception of the two growths from June beetles (Fig. 5 and 6), whose botanical characters are identical with those of Sporotrichum, these figures were made from growths resulting from the infection of living insects with spores from cultures made by us. The identity of these Isaria forms was further verified by raising the common Botrytis form from each of them on agar.*

*The club-shaped growths figured on this Plate (Fig. 1-4) had a general resemblance to Cordyceps; but they were merely tufts of fertile hyphæ, bearing profusely the usual heads of Botrytis spores all over the surface.

In addition to the above general summary, a fuller discussion of experimental methods and results will be found useful for the special student of this subject.

EXPERIMENTAL METHODS.

The culture apparatus used was in all cases either the common test tube with a cotton plug, or a glass fruit jar of the "Mason" pattern (usually of a capacity of two quarts), the metal cap of which screws on to the top of the jar with a flat rubber ring intervening. The caps were altered by closely soldering a tin tube into an opening in the top of each (see Plate V., Fig 1), as a safeguard against accidental infection by bacteria when the spores were sown upon the medium, and also for the purpose of convenient plugging with cotton as a subsequent protection.

In charging this jar with the culture medium, the metal cap was removed and the jar was partly filled with the corn-meal batter, mixed barely thin enough to settle smoothly, and was then placed upon its side, so that the mixture collecting at the lower part of the jar might present as large a surface as possible for the growth of the fungus. This culture jar worked very satisfactorily, any secondary infection of the culture rarely interfering with the growth and complete development of the Sporotrichum.

The cover of the jar was of course removed to get access to its contents, and if it was desired to preserve the culture for some time without deterioration, the jars were left open until the contents were dried out. (See Plate VI.) It was found that such dried masses of corn meal, with surfaces covered by Sporotrichum growths, could be readily and successfully freshened and revived after some months by simply moistening the mass.

The various experimental cultures of the season were greatly interfered with by the pressure of more practical operations, and little was added to our previous knowledge of the subject. The growths on peptonized agar were invariably prompt and profuse, excepting where the medium was too highly acid, or where the temperature approximated 100° Fah. (See Nos. 29-35 and 48-50.) Growth from the spores at ordinary temperatures was commonly noticeable by the second day; sometimes not until the third. Heads of spores were visibly formed on the fifth or sixth day, and were ripe on the eighth day, at the earliest. It was found that the fungus grew more profusely and luxuriantly on an acidulated medium than on an alkaline or neutral one.* (No. 29, etc.) A mixture of raw corn meal with water in which potatoes had been boiled was apparently better adapted for the culture of Sporotrichum than the batter of corn meal and beef broth, but this conclusion requires verification. The growth on these corn-meal mixtures was always at least as prompt and generous as on the agar.

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*This conclusion must be taken with reserve until verified.

Chinch-bugs in Boxes.—In our experiments with the transfer of muscardine to healthy chinch-bugs by enclosing them with specimens dead with disease in especially prepared boxes, we found that a layer of moist earth in the bottom of the box was an important aid to success, and that garden soil was better than sand. We had also abundant evidence that these experiments were most successful with weakened insects, and especially with those brought in from the field after the older generation present had passed its reproductive period and was consequently about to die. On the other hand, adults *in coitu* were occasionally found, one or both of which had died of muscardine.

Owing to unskilled methods of preparation and packing, and likewise to delays in transit, a large part of the material sent to the office was either dead when received or in a badly damaged condition. Although the worst of this material was always rejected, dead bugs accumulated so rapidly in our contagion boxes as to foul the contents, and to breed numerous blow-fly larvæ and masses of Anguillulidæ, and thus practically to interrupt the growth of the Sporotrichum. To avoid these disadvantages large reception boxes were prepared, each provided with a second bottom of coarse slats, a few inches above the first. The chinch-bugs received were placed on the lower bottom, and the vegetation used for food was laid upon the slats. When additions were to be made to the contagion boxes the stalks of corn and other food were taken out and beaten and shaken over the boxes, only the stronger and better-fed insects being thus transferred. The supposed weakening effect of close confinement in a saturated atmosphere was also avoided in this reception box by leaving it open, the escape of the bugs being prevented by heavily chalking the inside of each box for four or five inches downward from the top. This chalk-band was renewed occasionally, as it was worn away by the chinch-bugs in their efforts to escape. The same device was used to confine the bugs in the contagion boxes when these were opened. While this procedure had the effect to eliminate the difficulties due to dead and rotting insects, it also brought the development of the fungus practically to a stand, and it was not until these more hardy chinch-bugs had been kept in confinement for some weeks that they began to suffer noticeably from muscardine.

The difficulties due to the appearance of mites in the infection box have already been referred to. Minute Anguillulidae, so abundant among dead chinch-bugs as to form gray patches here and there, did not seem to affect the growth of the fungus, neither were the blow-fly maggots especially injurious to these cultures so far as we could observe. On the other hand, as both these forms devoured dead chinch-bugs indiscriminately, they doubtless interfered with the development of the fungus in the boxes.

CLASSIFIED LIST OF EXPERIMENTS, 1894—NOS. 1–91.*

Cultures on Agar-Agar.

No. 1. April 21. Neutral culture from dead insect larva.
No 6. June 28. Neutral culture from No. 1.
No. 11. July 2. Neutral culture from No. 1.
Nos. 29–35. August 2. Acid cultures from No. 11.
No. 43. July 3. Neutral culture from No 1.
No. 48. July 27. Neutral culture from No. 43. Temperature test.
No. 49. July 30. Neutral culture from No. 43. Temperature test.
No. 50. July 27. Neutral culture from No. 43. Temperature test.

Cultures on Corn-Meal Mixtures.

No. 2. May 7. Neutral culture in fruit-jar. From No. 1.
No. 7. July 6. Neutral culture on corn meal and agar gelatine. From No. 6.
No. 8. July 6. Neutral culture on corn meal and potato water. From No. 6.
No. 9. July 6. Neutral culture on corn meal and beef broth. From No. 6.
No. 10. July 9. Acid culture from No. 1.
No. 12. July 13. Neutral culture in fruit jar. From No. 11.
No. 13. July 13. Acid culture in fruit-jar. From No. 11.
No. 14. July 17. Acid culture in fruit-jar. From No. 11.
No. 42. July 3. Neutral culture in fruit-jar. From No. 1.
Nos. 44 and 45. July 20. Acid culture in fruit-jar. From No. 43.

Contagion and Infection Experiments with Living Chinch-bugs in Boxes.

No. 3. May 11. From agar culture No. 1.
No. 4. May 16. From agar culture No. 1.
No. 5. May 17. From agar culture No. 1.
No. 54. May 25. First contagion box. Kansas chinch-bugs.
No. 56. June 7. Farmer's contagion box, G. C. Wells. From No. 54.
No. 68. June 22. First large laboratory contagion box. From No. 54.
No. 69. June 23. Second large laboratory contagion box. From No. 54.
No. 70. June 27. Third large laboratory contagion box. From No. 69.
No. 71. June 28. Fourth large laboratory contagion box. From No. 2.

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* These numbers correspond to those of the descriptions of experiments following.

Laboratory Infection Experiments with Living Caterpillars.

Cabbage worms (Pieris rapæ):

Nos. 15 and 16. July 31. From acid corn-meal culture No. 14.
Nos. 18-20. July 28. From neutral agar culture No. 11.
No. 28. July 31. (Pupa). From neutral agar culture No. 11.
No. 51. July 27. From neutral agar culture No. 43.

Elm-leaf caterpillar:

No. 17. July 28. Infected from neutral agar culture No. 11.

Laboratory Infection Experiments with Dead Insects.

Chinch-bugs:

Nos. 36–40. August 2. From neutral agar culture No. 11.
Nos. 46 and 47. July 20. From neutral agar culture No. 43.

Cabbage worms:

Nos. 21–24. July 30. From neutral agar culture No. 11.
Nos. 25-27. July 31. From neutral agar culture No. 11.
No. 41. August 2. From neutral agar culture No. 11.

Sphinx larva:

No. 52. August 2. From neutral agar culture No. 43.

Field Experiments with Muscardine Fungus.

No. 53. April 20. Hollenbeck farm, near Tonti.
Nos. 55 and 56. June 7. Wells farm, near Farina. From contagion box No. 54.
Nos. 57 and 58. June 10. Wells farm, near Farina. From contagion box No. 56.
No. 59. June 7. Smith farm near Farina. From contagion box No. 54.
No. 60. June 15, Smith farm, near Farina. From contagion box No. 59.
No. 61. June 15. University farm. From contagion box No. 54.
No. 62. June 18. University farm. From contagion box No. 54.
No. 63. June 19. Bartley farm, near Edgewood. From contagion box No. 54.
Nos. 64 and 65. August 6. Bartley farm, near Edgewood. From corn-meal culture No. 2, and contagion box No. 68.
No. 66. September 4. Bartley farm, near Edgewood. From contagion box No. 68.
No. 73. August 7. Ferguson farm near Odin. From contagion box No. 68.
No. 74. August 7. Silver farm, near Odin. From corn-meal culture No. 2.
No. 75. August 7. Robinson farm near Odin. From corn-meal culture No. 2.
No. 77. May 15 and June 10. Heth farm, near Edgewood. From contagion box No. 54.

No. 78. June 25. Wilson farm, near Greenup. From contagion box No. 54.
No 79. July 1. Jackson farm, near Greenville. From contagion box No. 54.
No. 80. June 20. Filson farm, Xenia. From contagion box No. 54.

Spontaneous Outbreak of Muscardine.

No. 76. October 6. Hurd farm, near Odin.
See also No. 53, June 5; No. 55, June 7 and June 19; No. 57, concluding discussion; No. 60, June 19; Nos. 63-67, etc.

Effect of Moisture on Chinch-bugs.

No. 72. June 1. Bugs confined in saturated air.

Experiments with Barriers and Traps.

No. 81. July 10. University farm, furrow experiment.
No. 82. July 11. University farm, furrow and post-hole experiment.
No. 83. July 12. University farm, furrow and post-hole experiment.
No. 84. July 12. University farm, coal-tar and post-hole experiment.
No. 85. July 13. University farm, coal-tar and post-hole experiment.
No. 86. July 10. University farm, coal-tar and post-hole experiment.
No. 87. June 27. Bartley farm, near Edgewood, furrow experiment.
No. 88. June 28. Smith farm, near Farina, furrow and log experiment.
No. 89. June 15. Filson farmer, near Xenia, furrow, post-hole, and kerosene emulsion experiment.
No. 90. June 23. Mayo farm, near Falmouth, furrow experiment.
No. 91, June 25. Wilson farm, near Greenup, furrow and log experiment.

OUTLINE OF EXPERIMENTS WITH CHINCH-BUG MUSCARDINE FUNGUS (*Sporotrichum globuliferum, Speg.*) Nos. 1-80.*

April 21 to October 10, 1894.

No. 1. April 21. Agar culture, from dead insect larva.
  No. 2. May 7. Neutral corn-meal culture in fruit-jars.
    No. 64. August 6. Field experiment, Bartley farm. (See also under 68.)

* The subordination and dependence of these experiments, one upon another, is indicated by the indentation of the items on this list. For example, all the material for the first fifty-two numbers was derived, directly or indirectly, from the dead insect larva referred to under No. 1; experiments 64, 65, etc., down to 75, were begun with Sporotrichum grown as stated under No. 2; the cabbage worms mentioned under Nos. 15 and 16 were infected from the acid culture No. 14, itself the third remove from the dead insect—and so on through the list. The numbers in this outline correspond, of course, to those used in the full description of experiments next following. It should be noted, however, that No. 72 and the barrier experiments, Nos. 81 to 91, are not represented in this list.

No. 2 continued:

No. 65. August 6. Field experiment, Bartley farm. (See also under 68.)

No. 67. September 7. Field experiment, Bartley farm.

No. 71. June 28. Large contagion box in laboratory.

No. 74. August 7, Field experiment, Silver Farm.

No. 75. August 7. Field experiment, Robinson farm.

No. 3. May 11. Laboratory infection experiment with chinch-bugs.

No. 4. May 16. Laboratory infection experiment with chinch-bugs.

No. 5. May 17. Laboratory infection experiment with chinch-bugs.

No. 6. June 28. Agar culture.

No. 7. July 6. Test-tube culture on corn meal and agar gelatine.

No. 8. July 6. Test-tube culture on corn meal and potato water.

No. 9. July 6. Test-tube culture on corn meal and beef broth.

No. 10. July 9. Culture on acidulated corn-meal batter.

No. 11. July 2. Agar culture in twelve test-tubes.

No. 12. July 13. Fruit-jar cultures on neutral corn-meal batter.

No. 13. July 13. Fruit-jar cultures on acidulated corn-meal batter.

No. 14. July 17. Fruit-jar cultures on acidulated corn-meal batter.

No. 15. July 31. Infection experiment with live cabbage worms.

No. 16. July 31. Infection experiment with live cabbage worms.

No. 17. July 28. Infection experiment with elm-leaf caterpillar.

Nos. 18–20. July 28. Infection experiments with live cabbage worms.

Nos. 21–24. July 30. Infection experiments with dead cabbage worms.

Nos. 25–27. July 31. Infection experiments with dead cabbage worms.

No. 28. July 31. Infection experiment with pupæ of cabbage worms.

Nos. 29–35. August 2. Test-tube cultures with acidulated agar.

Nos. 36–40. August 2. Infection experiments with dead chinch-bugs.

No. 41. August 2. Infection experiment with dead cabbage worms.

No. 42. July 3. Fruit-jar culture on corn-meal batter.

No. 43. July 3. Test-tube agar culture.

Nos. 44 and 45. July 20. Fruit-jar cultures on acidulated corn-meal batter.

No. 46 and 47. July 20. Infection experiments with dead chinch-bugs.

No 48. July 27. Agar culture, temperature test.

No. 43 continued:

No. 49. July 30. Agar culture, temperature test.
No. 50. July 27. Agar culture, temperature test.
No. 51. July 27. Infection experiment with cabbage worms.
No. 52. August 2. Infection experiment with sphinx larva.

No. 53. April 20. Field experiment, Hollenbeck farm.

No. 54. May 25. Laboratory contagion box, Kansas chinch-bugs.

No. 55. June 7. Field experiment, Wells farm.
No. 56. June 7. Contagion box and field experiment, Wells farm.
No. 57. June 10. Field experiment, Wells farm.
No. 58. June 10, Field experiment, Wells farm.
No. 59. June 7. Contagion box. Field experiment, Smith farm.
No. 60. June 15. Field experiment, Smith farm.
No. 61, June 15. Field experiment, University farm.
No. 62. June 18. Field experiment, University farm.
No. 63. June 19. Field experiment, Bartley farm.
No. 68. June 22. Large contagion box in laboratory.
No. 64. August 6. Field experiment, Bartley farm. (See also under No. 2.)
No. 65. August 6. Field experiment, Bartley farm. (See also under No. 2.)
No. 66. September 4. Field experiment, Bartley farm.
No. 73. August 7. Field experiment, Ferguson farm.
No. 69. June 23. Large contagion box in laboratory.
No. 70 June 27. Large contagion box in laboratory.
No. 77. May 15 and June 10. Field experiment, Heth farm.
No. 78. June 25. Field experiment, Wilson farm.
No. 79. July 1. Field experiment, Jackson farm.
No. 80. June 20. Field experiment, Filson farm.

No. 76. October 26. Spontaneous outbreak, Hurd farm.

DESCRIPTION OF EXPERIMENTS.

1. *Experiments with the Fungi of Contagious Disease.*

The season's operations with contagious-disease experiments were developed principally from two points of departure: the first a single insect larva, indeterminable as to species, found April 17 dead and covered with the fungus of white muscardine, in a plowed corn field near Urbana; and the second a small lot of chinch-bugs dead with the same fungus infection, received from Chancellor Snow, of the University of Kansas, about May 15. From the first-mentioned material numerous cultures were made, and infection experiments were conducted on chinch-bugs, cabbage worms, and other insect larvæ, the series of operations dependent upon this original specimen extending from April 21 to September 20. From the second lot various laboratory and field experiments were started —twenty-one in number—extending from May 25 to October 10, all having the character of direct or indirect exposures of living chinch-bugs to contagion or infection by means of these dead specimens obtained from Dr. Snow.

Although several of the experiments here described were incomplete or otherwise unsatisfactory, I have thought it best to report the whole mass of them, as an assurance (if for no other reason) that nothing has been withheld because of its unsatisfactory character.

No. 1. April 21. A test-tube culture on agar, from a dead insect larva of undetermined species, found in a field at Urbana, Illinois. April 24, had barely begun to grow. April 27, spores had formed. April 30, spores ripe, the culture unmistakably *Sporotrichum globuliferum*. This larva and the culture derived from it are the starting point for all experiments of this list to No. 52, inclusive, as well as for Nos. 64, 65, 67, 71, 74 and 75 additional.

No. 2. May 7, six Mason fruit-jars, with caps altered to facilitate sterile culture (see Plate V., Fig. 1), partly filled with a batter of corn meal and beef broth and sterilized by dry heat for one hour on each of two successive days, were inoculated by spores of the muscardine fungus taken from culture No. 1. This second culture was successful, and furnished material for a large amount of subsequent experimental work.

No. 3. May 11, a lot of chinch-bugs received from F. O. Pierce, of Xenia, Clay county, was treated with spores from culture No. 1 and placed in a small wooden box which was kept on wet earth under a hedge, and covered again with a box of larger size. May 16 these bugs began to die. By the 22d all were dead but one, and an external growth of the Sporotrichum had begun to appear upon three. All were then returned to the sender for distribution in his fields.

No. 4. A precisely similar experiment with chinch-bugs from Trenton, Illinois, was begun May 16, the experimental box being similarly placed. On the 19th some of the bugs were dead; on the 22d an external fungous growth appeared upon two of them, as yet, however, without spores; on the 25th many more were dead, several of them covered with a white mycelium; and by the 29th nearly all had perished, development of the characteristic spores on several of them now giving unmistakable evidence of the presence of *S. globuliferum*—the special fungus of the muscardine disease. Specimens returned to the sender.

No. 5. On the 17th of May a second lot of bugs from Xenia were similarly treated, with a similar result. Beginning to die May 19, most of the bugs were dead on the 22d, and on the 29th all had perished. A slight external growth appearing at this date resembled in every way the immature mycelium of the muscardine fungus. Without waiting for further evidence of infection this lot of bugs was returned to the sender.

No. 6. Next, on the 28th of June, nearly two months from the original agar culture (No. 1), a second agar tube was infected from that growth. July 6, this culture was ripe, and the spores were used for the experiment next succeeding.

No. 7. July 6 a test-tube culture of corn meal and agar gelatine was infected from culture No. 6—the third remove from the dead insect. July 9 this had made a good start, but was not followed further.

No. 8. July 6. This was an experiment identical with No. 7, and begun at the same time, varying only in the culture medium used, which was a batter of corn meal mixed with water in which potatoes had been boiled. Three days later, July 9, the spores were starting abundantly, but the matter was not followed further.

No. 9. July 6. This was a companion experiment to the two preceding, except that our ordinary mixture of corn meal and beef broth was used in place of the foregoing media. July 9, growth had begun, but less vigorously than on either of the others.

No. 10. July 9. A corn-meal batter, like that of No. 9, but acidulated with acetic acid, was infected with ripe spores from No. 1. July 11 it had made a good start, but was not followed further.

Nos. 7, 8, and 9, derived from No. 6, were intended originally to test the comparative value of various corn-meal mixtures. The exigencies of the season's work prevented their completion, and they serve merely to give some hints suggestive of further trials.

No. 11. July 2. This was a repetition of No. 6—a set of agar test-tube cultures, twelve in all, the spores for which were derived from No. 1. July 5 all were freely growing, and July 9 the growth was spreading rapidly. These tubes were not again reported on until August 13, at which time an abundant development of the muscardine fungus was noted on all, the gelatine having, however, in the meantime quite dried up. A long series of cultures on corn meal and of infection experiments on chinch-bugs and cabbage worms, and other larvæ, were made with spores from this set of tubes.

No. 12. July 13, 1:30 p. m., several fruit-jars of the corn-meal mixture with beef broth, neutralized with sodium carbonate, were infected with spores from No. 11. Two days later, July 15, these spores had begun to grow, and on the 17th the growth covered a part of the surface.

No. 13. July 13, at 1:30 p. m., spores from No. 11 were sown on acidulated mixture of corn-meal and beef broth which had been placed in altered Mason fruit-jars and sterilized by heat as already described. On the 15th growth had begun, and on the 17th the surface of the meal was covered.

No. 14. July 17, at 2 o'clock p. m., fourteen Mason fruit-jars of the acid mixture of corn meal and beef broth, sterilized by heat on two successive days, were infected with spores from No. 11. On the 19th the growth had started, and on the 21st it had become very abundant, distinctly more so indeed on both these acid mixtures (13 and 14) than on the neutral mixture, No. 12.

No. 15. July 31. An infection experiment on living cabbage worms with spores from the acid corn-meal culture, No. 14 of this list. Two cabbage worms were infected on the back near the head, and were then shut up in a large covered glass dish which had a layer of moist sand on the bottom, on which a fresh cabbage leaf was placed for food. August 1 no growth had appeared on either cabbage worm. August 2, still no growth, but one of the larvæ had pupated. August 3, still no growth. August 7, one larva dead, softened, and blackened, but without appearance of fungous contamination. The pupa also dead and softening. August 13, no Sporotrichum apparent, only softened bodies of larva and pupa remaining.

No. 16. July 31. An experiment parallel with the preceding, three cabbage worms being infected on the back. Results identical with those of No. 15, one worm pupating August 2. Both larvæ and pupa died, blackening and becoming deliquescent, without appearance of muscardine. The pupating larva proved to have been parasitized, as is noted August 7.

These two experiments with infection material derived from acid cultures throw some doubt on the effectiveness of that kind of material, but as the larvæ evidently died from the common bacterial disease of the cabbage worm, it is possible that the previous presence of this disease prevented the development of the fungus—an hypothesis that is made more probable by the fact that spores of Sporotrichum will not germinate on decaying media.

No. 17. July 28. An infection experiment upon the larva of a butterfly (*Grapta interrogationis*) taken from the elm. This caterpillar was infected with spores from agar culture No. 11, itself derived, as will be remembered, from agar culture No. 1, derived in turn from the dead larva with which this series began. The material here used was consequently at two removes from the dead insect. The spores were placed along the center of the back of the caterpillar at 10:30 a. m., the infected insect being then shut up in a large covered glass dish, with a layer of moist sand on the bottom, upon which leaves of elm were scattered as food. At 9 a. m., July 30, this larva had pupated, of course casting off the skin upon which the spores had been placed. It was examined daily without note of change until August 7. The pupa at this date was still alive and apparently healthy, but exhibited a slight growth of Sporotrichum from a point about the size of a pin-head on the ventral surface, at the edge of the pupal wing-pads. This ventral point was in immediate contact with the cast skin still bearing the fungus spores. August 13 this pupa was dead, with a slight external growth of *Sporotrichum globuliferum*—at that time in fruit.

No. 18. July 28, 10:00 a. m. An infection experiment similar to the preceding, except that a cabbage worm (*Pieris rapæ*) was used instead of the Grapta larva, and that a cabbage leaf was placed in the dish instead of leaves of the elm. The caterpillar was touched with spores from No. 11 on the back, immediately behind the head. July 30 the fungus was growing freely from the point of infection and spreading to the sides of the body. July 31 it had enveloped the body near the head, and had also extended on the ventral surface the entire length of the caterpillar. The color of the larva had in the meantime changed to that of crushed raspberries wherever the fungus was growing, and August 1 the entire cabbage worm was of the same crushed-raspberry color. August 2 the Sporotrichum had spread all over the surface, and August 7 it was well developed everywhere and covered with ripe spores.

No. 19. July 28. An infection experiment precisely like the last, except that the spores were placed along the right side of the caterpillar only. Two days later the fungous growth was abundant all along this side wherever the spores had lodged, but it had not yet begun to spread. A very fine white web had fastened the larva to the dish upon which it was resting when it died. July 31 nearly the entire body was covered by the mycelium of Sporotrichum, leaving only the two ends free, and the larva had begun to change to the crushed-raspberry color. August 2 the whole body was covered, and later the spores developed everywhere, as before.

No. 20. July 28. Like the preceding, except that the spores were applied only at the posterior end of the back. July 30, growth abundant at the point of infection, covering about a fourth of the back, but not extending downwards to the sides. A very fine white web fastens the larva to the cover. July 31, growth of mycelium very abundant at point of infection, and extending downwards, underneath the body, to the hinder end, the crushed-raspberry color appearing wherever the fungus has taken hold. August 1, growth slowly extending downwards. August 7, spores well developed on the dead larva.

Experiments 15, 16, 18, 19, and 20 of the foregoing series show the efficiency of this fungus as a means of infecting living cabbage worms, and bring to light also the interesting fact that its growth may have the effect to color the larva red.

We have next a series of experiments intended to test the possibility of the growth of Sporotrichum on insects dead when infected. For this purpose, cabbage worms killed with chloroform were used.

No. 21. July 30, 1:30 p. m. Chloroformed cabbage worms placed in covered glass dish on piece of cabbage leaf on moist sand, and spores of muscardine (Sporotrichum) from No. 11 sown along the back. July 31, 8:30 a. m., no growth visible. August 1, 9 a. m.. slight growth along the back. August 2, 8:30 a. m., growth very abundant on the back. August 7, 3 p. m., Sporotrichum well developed on this larva. Specimen preserved.

No. 22. July 30. This was an experiment like No. 21, except that the cabbage worm was infected on the ventral surface. July 31, growth not started. August 1, beginning to grow. August 2, growth very abundant and spreading over the entire body. August 7, Sporotrichum well developed. Specimen preserved.

No. 23. July 30. Same as the foregoing, but infected along the side. Examined August 1, 2, 3, and 7, with results exactly as above.

No. 24. July 30. Exactly as above, except that several caterpillars were infected on the head. July 31, growth not started. August 1, no growth as yet, except that a fine cobweg fungus has started on a single worm. August 2, the above worm completely enveloped in the cobweb growth. August 3, heads of spores just beginning to show. At this point the above experiment was accidentally interrupted.

Nos. 25, 26, and 27. July 31. Dead cabbage worms as above. Experiments identical with the foregoing, and made at the same date, except that infected spots were touched with sterilized distilled water to cause the spores to adhere to the worm. The results were all as above mentioned, with a slight variation in No. 27. Here, August 1, no growth of the spores had appeared, but one larva had become fastened to the cover by a fine white web. On the 2d the growth was spreading feebly, and on the 3d the worms were turning crushed-raspberry color, the one on the cover having the Sporotrichum growth well started. August 7, this fungus was fully developed on all, and the specimens were put aside for preservation.

No. 28. July 31, 10 a. m. Three pupæ of cabbage worms placed under same conditions as No. 21, and infected with Sporotrichum from No. 11. August 1, no growth. August 2, two of the pupæ turning reddish, but no growth. August 3, still no growth, but one of the pupæ of a deep red tint. August 7, two of the pupæ dead, one of them showing a slight mycelial growth of Sporotrichum. The third has yielded a healthy butterfly.

Nos. 29 to 35 are agar test-tube cultures, in which the gelatine was acidulated variously, it being the purpose of these experiments to determine the degree of acidity of the medium most favorable to the germination of the spores and the development of the fungus.

No. 29. August 2, $3\frac{3}{4}$ cc. of agar gelatine and $\frac{1}{4}$ cc. of a one eighth per cent. solution of acetic acid in test-tube, sown with spores of *Sporotrichum globuliferum* from No. 11. August 13, no Sporotrichum growing, spores apparently not having started.

No. 30. August 2. Like 29, except that the acetic acid was in a one fourth per cent. solution. August 13 there has been apparently a slight growth of Sporotrichum in this tube, but it is now all dead.

No. 31. August 2. Like 29, except that the acetic acid used was a one half per cent. solution. August 13, a small straggling growth of Sporotrichum has appeared and has formed spores.

No. 32. August 2. As above, except that the acetic acid was a one per cent. solution. August 13, fair growth of Sporotrichum, covering most of the agar surface. Spores abundant, ripe, but not of yellowish tint.

No. 33. August 2. As above, but acetic acid now a two per cent. solution. Result identical with no 32.

No. 34. August 2. Like no 29, except that the acetic acid is now a five per cent. solution. August 13, no growth whatever.

No. 35. Like No. 29, except that the acetic acid used was a ten per cent. solution. August 13, no growth.

From the foregoing it appears that an agar mixture containing from three to six hundredths of one per cent. of acetic acid is that which proved most favorable to the growing of Sporotrichum. These experiments should be repeated, however, for verification before the statement is accepted.

Next, I report five experiments with dead chinch-bugs, intended to test the possibility of the infection of this insect after death by other causes. (See also Nos. 46 and 47.)

No. 36. August 2. Fifteen chinch-bugs killed by crushing were placed in a covered glass dish, and treated with spores from culture No. 11. August 3, no appearance of growth. August 7, the dish a mass of mold, which fills the entire interior; no appearance of a growth of Sporotrichum on the bugs. August 13, no development of Sporotrichum in this experiment.

No. 37. August 2. A duplicate of No. 36, with precisely the same result.

No. 38. August 2. Chinch-bugs killed with chloroform, placed on a cabbage leaf on moist sand in a covered glass dish and infected with Sporotrichum from No. 11. August 3, no growth. August 7, no appearance of infection; specimens beginning to mold. August 13, no Sporotrichum to be found.

No. 39. August 2. Equivalent experiment, except that the bugs were placed immediately on sand. No growth August 3. August 7, 3 p. m., slight appearance of Sporotrichum on legs, antennæ, etc., of single insects, here and there.

No. 40. August 2. The same as 38, August 3, no growth. August 7, loosely covered with bluish mould; no Sporotrichum formed.

No. 41. August 2. Infection experiment with dead cabbage worms. Equivalent of No. 25. August 3, no growth. August 4, development of Sporotrichum commencing on all these cabbage worms. August 7, Sporotrichum well grown, with some appearance of *post mortem* mold.

No. 42. July 3. A fruit jar culture on corn-meal batter made with beef broth, the spores for which were taken directly from agar culture No. 1. A successful growth, not requiring detailed report.

No. 43. July 3. An agar culture in five test-tubes, made, like 42, from No. 1. Developed readily and matured in due season, being subsequently used for a considerable number of cultures and infections.

No. 44. July 20. Fifteen jars of the acidulated corn-meal mixture (degree of acidity not given) infected with Sporotrichum from No. 43 at 1:30 p. m. These cultures were all well started July 23, and matured in due season, eight of the fifteen being, however, somewhat contaminated by Aspergillus. The contents of these jars were subsequently used in part for chinch bug infection experiments on the large scale.

No. 45. July 20. Culture like 44, differing only by an abbreviation of the sterilization process. Previous to this jars had first been sterilized by heat while empty, then stocked with the corn-meal mixture and sterilized again. In the present culture, jars and batter were sterilized together, once for all. Result the same as in 44.

No. 46. July 20. Chinch-bugs killed by chloroform were placed dry in a test-tube, treated with Sporotrichum from 43, and left with the test-tube plugged with cotton. July 28, no fungous growth.

No. 47. July 20. Like 46, except that the chinch-bugs were moistened with distilled water before being placed in the tube. July 28 and August 13, no growth at either date.

July 27, a beginning was made with experiments intended to determine the temperature at which Sporotrichum would grow most freely.

No. 48. July 27, 11 a. m. An agar test-tube sown with spores from No. 43 and kept in laboratory at temperature of 80° Fah. July 28, 8:30 a. m., 74° Fah.; 11:30, 79° Fah. July 30, 8:15 a. m., 74° Fah., growth starting nicely. The average temperature by day in this culture was about 77°.

No. 49. July 30. Another tube, as above, placed in south window, temperature ranging from 77° to 95° Fah. July 30, growth well started.

No. 50. July 27. Agar tube, as above, placed in incubator at 97° Fah. at 11 a. m., and kept there at a constant temperature of 100° Fah. July 30, growth not starting. August 13, these spores did not germinate.

No. 51. July 27. An experiment with cabbage worms infected from No. 43. Several caterpillars (*Pieris rapæ*) placed under a sterilized glass bell-jar with a large piece of fresh cabbage leaf lying on table without moist sand. Spores were shaken from agar culture and spread upon the worms with a sterilized platinum wire. July 30, several worms have died, but without appearance of fungous growth. One example, however, shows growth near the hinder end, and has turned black about one fourth of its length. July 31, the cabbage worm just mentioned has turned a crushed-raspberry color, and the Sporotrichum has begun to spread over the surface. Another larva has turned a similar color, and a Sporotrichum growth is appearing at one point. August 1, several of the worms have become crushed-strawberry color, but without visible growth. One has become brownish-green, and on this Sporotrichum filaments have appeared externally. August 7, everything dead but one imago recently emerged. Ten died in pupa stage; two larvæ parasitized. August 13, very little external development of fungus has appeared in this lot of worms.

No. 52. August 2. Large sphinx larva (Protoparce) chloroformed, and placed in a large culture dish upon a cabbage leaf resting on moist sand. Spores from culture 43 sown upon the right side. August 3, no growth. August 7, mixture of fungi all over surface, but infected area with a conspicuous white patch. August 13, no *Sporotrichum globuliferum*, only common mold.

No. 53. This is a farmer's contagion experiment made by Mr. C. S. Hollenbeck, near Tonti, Illinois, and not observed by us in the beginning. Infection material originally obtained from my office September 7, 1893, and used to start contagion box, the contents of which were afterwards distributed in his fields with a result which he regarded as successful last fall. The box, with a considerable number of chinch-bugs remaining, was kept over winter in a warm and rather moist cellar, and about April 20 its contents were scattered in wheat in a young orchard, care being taken to place the material where bugs were thickly congregated.

The weather at the time was damp, cloudy, and warm. Mr. Hollenbeck reports that about a week afterwards he saw many moldy bugs in the field, other than those put out, and was convinced that these bugs were killed by the fungous disease.

May 24, this wheat was examined by Mr. Marten, who reported the chinch-bugs very abundant in the wheat, copulating and depositing eggs. Search for the greater part of a day on this farm and one adjacent, yielded only two fungus-covered chinch-bugs. On another visit, made June 5, the fungus disease was found generally distributed in this and adjoining fields, as it was at that time throughout this part of the State at large; but June 20, after an interval of drought, no trace of it could be found by Mr. Marten in these same fields. The young bugs at this time were plentiful, a few having reached the pupa stage.

No. 54. A contagion experiment, the first of a long series (see Outline, p. 102) derived from a small lot of chinch-bugs, dead with *Sporotrichum globuliferum*. received from Dr. Snow about May 15. May 25 a lot of chinch-bugs from the vicinity of Tonti and Odin, in Marion county, collected by Mr. Marten, together with others received from fourteen farmers of that vicinity, were placed in a wooden box which had been thoroughly wet inside and out, and the bottom of which was covered with a layer of green wheat for food. With these bugs the material obtained from Dr. Snow was placed. The box so prepared was tightly closed and kept on damp sand upon the ground in the insectary. It was opened for examination about every other day and supplied with fresh food. May 26 more bugs were added, but no dead insects were observed. May 28 another lot from Southern Illinois was introduced, and still another on the 29th. No dead were seen at this time, and there were no traces of muscardine infection. On the 30th a few bugs were dead in the box, two of them well covered with another chinch-bug fungus, *Entomphthora aphidis*, but no fresh Sporotrichum was seen.

More live insects were introduced May 31 and June 1, at which latter date the dead bugs were a little more numerous. June 4, the box had warped and split, and more than half the bugs escaped; otherwise the experiment was in good condition. The white muscardine had now taken effect, and a sufficient number of fungus-covered chinch-bugs were taken out to supply the fourteen farmers near Tonti and Odin, from whom the material was received May 25, together with four farmers at Farina, in Fayette county. Among these last were G. C. Wells and James Smith, whose farms were frequently visited by us later (see Nos. 55 to 60). The lot sent to Tonti and Odin was delivered June 5, and that to Mr. Wells and Mr. Smith June 7, a part of this latter material being used by Mr. Marten for the field experiment on the Wells farm, reported at length under No. 55

June 9 all the material was taken from the above box and placed in a second, similar one. June 11 this second box was overhauled and a sufficient number of fungus-covered bugs was removed to make up twenty packages, two lots of living bugs being at the same time added. June 12 and 13 more live bugs were added, and a few dead ones were taken out. June 14 the condition of this lot was regarded as unsatisfactory, and everything was again transferred to a clean box. Of those which were dead a few were covered with muscardine fungus, but at least a hundred times as many gave no external trace of muscardine. Five additional lots from various places were now introduced, and the box was a second time infected, by means of fifty chinch-bugs covered with ripened Sporotrichum collected by Mr. Marten in wheat fields at Tonti and Farina June 6 and 7 (see No. 55). June 15 thirteen lots more were placed in this box, and a quantity of fungus-covered dead were removed and distributed in spring wheat on the University experimental farm (see No. 61). June 16 a quantity was taken out for shipment, and seventeen packages from farmers were introduced. June 17 six lots more were placed in this box, and June 18 four more. On this last date both old and young were dying with white muscardine, and a few with Entomophthora. About three thousand live bugs from this box were now distributed in spring wheat on the University farm (see No. 62), and a lot of dead bugs removed and prepared for shipment, together with a quantity of both dead and living for use in fields in southern Illinois (see No. 63). June 20, box overhauled, dead bugs removed and distributed to farmers. June 22, emough material removed to supply fifty-one farmers, after which the entire contents were transferred to two large boxes in Natural History Hall (see Nos. 68 and 69).

No. 55. June 7. A field infection experiment, started by Mr. Marten in a $4\frac{1}{2}$-acre wheat field on the Wells farm, represented at A, Plate I. Chinch-bugs abundant, literally covering the wheat in many places, especially in the northeast corner adjoining corn (D). A dozen bugs dead with the white fungus, collected from the ground in wheat at this time, were afterwards placed in No. 54. Diseased insects locally present in all fields examined. About one hundred fungus-covered chinch-bugs from No. 54 distributed along the second and third drill rows, at the bases of plants where live bugs were most numerous, for a distance of several rods on the north and east sides, in the northeast corner (indicated by the heavy dotted lines on Plate I).

June 19, field examined by Mr. Marten. Fungus-covered bugs about as abundant throughout the wheat as on the former visit. No indication that the disease had spread, or was any more prevalent in the vicinity of the spot where the dead bugs were distributed than at other places. Many fields examined in this neighborhood not entered on former visit. Diseased bugs found in all in moderate numbers. A second lot of infection material, consisting of several hundred bugs dead with this fungus, from No. 54, scattered on the ground in several drill rows in the immediate vicinity of those previously distributed. Wheat badly damaged and considerably lodged in several places. Bugs everywhere abundant, advancing into corn (B and D). June 20 Mr. Marten revisited the field (A) to examine two spots (*a* and *b*), each about one rod in diameter, where manure had been piled previous to being scattered, and where the wheat was badly lodged. The ground was here quite damp, and chinch-bugs had collected in considerable numbers. The muscardine fungus was also much more abundant here than elsewhere in the field, and several hundred whitened bodies could have been collected. It was, however, thought advisable to allow them to remain, in order to determine, if possible, whether or not the disease would spread from these centers of spontaneous development. Wheat cut June 25, but so far as could be seen, according to Mr. Wells, the fungus had not spread.

July 11 a few traces of the original material were found by Mr. Marten in the northeast corner. A few whitened bodies were under the fallen wheat at *a* and *b*, but the fungus was apparently a week or ten days old, and there was no indication that the disease had spread from these places. Only an occasional live insect seen in the stubble, the great majority having migrated into adjoining corn (B and D), where considerable mischief was done. Several rows in the latter field had already been killed, and the corn was blackened with bugs for several rods. In the former field, however, the bugs were not quite so abundant, their progress being checked by a narrow lane 1 rod wide and an orchard (E) 4 rods wide, thickly grown up with weeds and grass, which separated A from B. The chinch-bug hordes were constantly emerging from the grass, however, and entering the corn. Many were hiding under clods and rubbish in both fields, but not one was found dead with any kind of fungous growth.

Mr. Wells reported August 8, that, in his opinion, we had wasted our labor, as he could not find any indication that the disease had spread to any part of his farm.

No. 56. A farmer's contagion experiment conducted by Mr. Wells, and examined several times during the season by Mr. Marten and Mr. Johnson. The box, 12x18x16 in., was prepared according to our directions (see p. 90), with a bottom layer of dirt half an inch deep, moistened and covered with a layer of corn leaves and green wheat. About two dozen diseased chinch-bugs from No. 54 were placed in the box June 7, together with a little more than a quart of live insects collected from wheat and corn in the neighborhood of No. 55. The box thus stocked was tightly closed, covered with a wet grain sack, and kept in the cellar on the damp floor.

June 10, nearly a quart of insects, both dead and alive, were removed from the box, several hundred of the dead being well covered with the fungus. All the insects, both dead and alive, were used for starting infection experiments in corn and oats (see Nos. 57 and 58). Several dozen whitened bodies were left in the box, into which about a pint of live insects collected from corn (B) were put, together with a fresh supply of corn leaves for food. The box remained in good condition and was supplied with fresh food and live insects about every third day. June 20 the second lot of material was removed,—about three pints in all,—consisting, as before, of dead and live insects. Box examined by Mr. Marten and found in excellent condition; several dozen bugs dead and covered with a fresh fungous growth left in the box; fresh food and about one half pint of live insects introduced.

Box supplied with live insects and fresh food as needed. June 30, condition of the box about the same as above. About one quart of chinch-bugs removed and placed in corn (B). Fresh food and about one pint of insects introduced. The box was left undisturbed, except when fresh food and live insects were put in, until the latter part of July. On one occasion, about the middle of July, Mr. Wells found a large insect, which he took to be a cockroach, under the box, "thickly covered with the same white fungus." It was removed and placed behind a leaf sheath on corn (B) among "a teaspoonful of chinch-bugs," and left several days, without any indication that the disease spread to the insects coming in contact with it. It was afterwards placed behind another leaf, similarly covered with chinch-bugs, where it remained; but at no time were there any traces of the fungus on the insects about it.

August 1, the box in good condition, and several thousand fungus-covered bugs removed, together with nearly three fourths of a quart of live insects, all of which were placed in corn (B), as recorded under the following number. Fresh food and about one gill of live insects added; the box set away and not examined again, until September 19, at which time it was overhauled by Mr. Johnson. Insects all dead; the dirt in the bottom somewhat dry, and the food considerably molded; but the whitened bodies of dead chinch-bugs were very abundant. Several thousand well-covered specimens could have been taken out, but the supply was reserved for further use.

Mr. Wells informed Mr. Marten August 8 that his contagion box did not work so well after he began putting in immature bugs; but that, altogether, he had distributed in corn about four quarts of chinch-bugs that had passed through his box.

However successful this experiment may seem to have been, it must be borne in mind that the chinch-bugs introduced from time to time had been liable to infection in the fields where they were collected (see Nos. 55 and 57), as well as in the contagion box itself.

No. 57. A farmer's field infection experiment made by Mr. Wells on his farm near Farina, in corn (B). The first lot of material, about two thirds of a quart of chinch-bugs, dead and alive, from his contagion box (No. 56), was distributed June 10 behind the leaf sheaths and on the ground of the first, third, and fifth rows along the south and east sides, where the bugs covered the first five rows of corn. This field was examined by Mr. Marten June 19, but no dead bugs were seen, and only a few traces of the original material were found. The chinch-bug attack was spreading rapidly, and corn was badly damaged throughout the south and east parts of the field.

The second distribution was made June 20, the material consisting of about three pints of chinch-bugs, dead and alive, from No.

56. The first three rows on the south, east, and west sides were treated as above. Examined by Mr. Wells June 25. No indications that the disease was spreading.

A third distribution was made June 30. About one quart of chinch-bugs, dead and alive, from same source as the others, were scattered, as above, in the second, third, and fifth rows on the west and north sides. Mr. Wells examined field July 5, but found no bugs dead with the fungus, save a few scattered fragments of the original material. Mr. Marten examined it (B), as well as neighboring fields (D and F), July 11. No traces of the disease were found at this time on this farm, except a few weathered specimens in wheat (A), as noted in experiment 55. All the corn on this farm was dwarfed and ragged. The bugs were everywhere abundant, covering the stalks in many places throughout the fields.

The fourth, and last, distribution was made August 1. Three fourths of a quart of chinch-bugs, dead and alive, from No. 56, were distributed, as above, along the west side in the third, fifth, and seventh rows, and in three alternate rows through the center of the field. Mr. Wells examined the field August 5, and reported that he could find no signs of the fungus other than a few traces of the original material.

From the above it will be seen that nearly four quarts of chinch-bugs, thoroughly exposed to the disease, were scattered in corn (B), two distributions each being made on the south, east, and west sides, one on the north, and one through the center of the field, as represented by the heavy dotted lines on the plate. Nevertheless this fungus practically disappeared from this farm during July and August, and did not appear again until about the middle of September. The chinch-bugs, however, continually increased in numbers, and caused far greater loss to corn than the drouth in this vicinity. September 4 Mr. Johnson found a few traces of the original material along the south and east sides of the field (B). No fungus found in corn marked D, although live bugs were very abundant throughout the field. Nothing indicating the presence of the white fungus was seen in corn marked F, or in any other field on this farm, except the one (B) just mentioned. A few bugs were found in all the meadows and pastures adjoining corn, but all traces of the local fungus-outbreak which had appeared in June had now utterly disappeared.

Nothing further of importance was noted from this neighborhood until September 18, at which time the following interesting information was received from Mr. Wells: "I have been cutting corn and find diseased bugs scattered over the ground, especially under stalks lying on the ground. I have seen 30 or 40 under a single ear. I have worked with this disease with your assistants, and know what I am talking about. There are still hordes of live bugs in the field."

The field referred to proved to be that marked B, and was carefully examined by Mr. Johnson September 19. The corn had been cut and shocked, the work having been finished the previous day. The ground was rather damp, but not muddy except in the southeastern part, which is somewhat lower than the rest of the field. There had been a heavy rain September 4, and according to Mr. Wells a slight shower had fallen about September 11, followed by a heavy rain again on the 16th. The east-central, southern, and southeastern parts of the field were rather weedy, and the corn had fallen here much more than elsewhere. The weeds, broken corn stalks, and leaves almost completely covered the surface of the ground, which was quite damp and rather sticky in such places. Chinch-bugs had collected here in considerable numbers, and whitened bodies covered with Sporotrichum were very conspicuous behind leaf-sheaths, on the stubble, on the surface of the ground in the open field, under clods, bits of fallen leaves, sticks, and rubbish of all kinds; on the ground under weeds and grasses; in corn shocks, on the stalks, behind the leaves; and on the ground under the shocks. They were, in fact, generally distributed throughout the field, being most abundant in those portions thickly covered with weeds, corn, etc., as indicated above. At a point, *c*, under a dense cluster of weeds where the ground was quite damp, Mr. Johnson collected 157 fungus-covered bugs from a surface area of two square feet; 68 were counted at *d* within a radius of ten inches, and 39 were found under a single shock at *e*. Similar examples were reported from all parts of the field. The great majority of the insects attacked by this fungus were adults, although several young of the first and second moults were seen.

Live chinch-bugs were abundant throughout the stubble, and accumulated in great numbers in the shocks; but there was a general movement in all directions into adjoining meadows and pastures. The larger part were in the pupa stage, although all ages were seen, even those just emerged from the egg.

No traces of the disease were found at this time in the wheat stubble (A), and only an occasional bug dead with the fungus was seen in corn D. Seven whitened bodies were collected in the vicinity of *f*. The entire northwestern part of this field had been invaded by chinch-bugs from wheat A, and was seriously injured; other portions suffered less damage.

In an eight-acre field of corn (F) to the north of D and east of B, the chinch-bug injury was very much more complete than in the latter, and about the same as in the former. Dead bugs covered with Sporotrichum were very numerous, being almost, if not quite, as abundant as in B. The corn had not been cut, and the diseased bugs were found behind leaf sheaths, under fallen stalks on the ground, around the hills and between the rows, and under clods, leaves, weeds, grasses, and other rubbish. Seventy-eight whitened bodies were counted on the ground under a single fallen stalk near the center of the field. Live bugs, mostly adults and pupæ, were everywhere abundant, and completely blackened the corn in many places, especially through the central and east-central parts. According to Mr. Wells's estimate, one-third of the entire field was completely ruined at this time.

It must be borne in mind that not a single diseased insect was artificially introduced into this field at any time during the season, and that no traces of the fungus were found by Mr. Johnson at the time of his former visit, September 4. It seems quite possible, therefore, that the spores of this fungus were quite as abundant in F as in B, and that the parasite developed spontaneously in both fields when conditions fostered the growth of the germ.

All other corn fields within a radius of three quarters of a mile were examined, but nothing was seen indicating the presence of the fungus. All the corn seen was badly damaged, and chinch-bugs were still very numerous.

Mr. Johnson examined the fields in this neighborhood again September 28. The afternoon was very warm and calm, and the air was full of chinch-bugs flying in all directions. Mr. Wells said that they had been flying in great hordes the preceding day. The fungus was no more abundant in the corn stubble (B) in the open field than at the time of his former visit, but the attack had increased in the shocks. Fifty-one chinch-bugs dead with muscardine were taken from a surface area of one square foot under a shock near the center of the field where the bugs were still concentrated. Only a few were seen in the stubble. Grass along the lane and in the orchard between B and C was alive with bugs, but no dead were seen among them. The four-acre meadow between B and F was damaged to a slight degree, and all the meadows and pasture lands in the immediate vicinity of corn were more or less injured.

Several fungus-covered bugs were found half a mile east of the Wells farm, along a dead furrow, in a field of corn where the ground was quite damp and the corn considerably lodged. No Sporotrichum had been found in this field September 18. Evidence of the chinch-bug muscardine was also quite common in low, damp places in an adjacent field of corn. Five or six whitened bodies could commonly be seen under every fallen stalk. About the same condition existed in corn one third of a mile south of the latter field. The fungus was quite common in a five-acre corn field west and north of C, on the opposite side of the road, belonging to Mr. Thomas Aringt n. It was easy to find a dozen or more dead bugs covered with Sporotrichum under almost any piece of fallen herbage, or under pumpkin vines, which were common throughout the field. About two and a half acres of the corn had been completely destroyed by chinch-bugs coming from wheat on the south side, leaving only an occasional stalk standing here and there. An hemipterous insect (*Nabis fusca*) imbedded in this fungus, was found on the ground under a cluster of grass by the roadside opposite the northwest corner of C.

The disease was also found in a twelve-acre field belonging to Mr. A. C. Rogers, one half mile west of the Wells farm. About half the corn in the field had been cut, the greater part of the remainder being flat on the ground. The stalks were dwarfed, the leaves dry and brown, and the ears were little more than soft cobs, with an occasional imperfect grain attached to them. Chinch-bugs, mostly adults and pupæ, were very abundant behind leaves at bases of stalks, where the plants were somewhat green, and under every cluster of grass about the field. In the open field, where the corn had been recently cut and where the ground was rather damp, eighty-three dead bugs imbedded in this fungus were counted under a single stalk, and whitened bodies could easily be found under any bit of rubbish or piece of herbage about the field. Two fungus-covered chinch-bugs were found in a field half a mile south, and traces of this fungus were found in all other fields examined in this vicinity at this time. From the foregoing, it is clear that the white fungus was generally present in this neighborhood, having been found in all fields examined.

The final visit to this section was made by Mr. Johnson and myself October 10. The fungus-covered bugs were not so abundant in the open field (B) as formerly, although traces of the disease were still present on the ground under grass, weeds, and rubbish of all kinds; but only an occasional dead bug was seen which bore a fresh fungous growth. As a rule, dirty whitish spots, scattered irregularly over the ground here and there, were all that remained of the older examples.

Very few live insects were seen in the corn stubble at this time. An occasional cluster of foxtail-grass was thickly covered with adults and pupæ, but in such places dead insects with a fresh fungous growth were very rarely seen.

The bugs were still accumulated in the shocks, especially along the south side of the field; perhaps because this was the last corn cut and was greener and better suited for food. In such places fungus-covered bugs were quite common, many of them apparently just dead, as the white cottony growth was just appearing on their bodies. The fungus attack, however, had not increased since our last visit, but on the other hand had perceptibly diminished.

Adults and pupæ were quite numerous in grass along the lane north of B, but were less than half as abundant as nine days previous. This reduction was probably due to the flight of the winged individuals, and not to any contagious disease, as not a single dead insect was found. We did not examine the fields D and F, as Mr. Wells told us the condition of affairs was about the same as on our previous visit.

Sporotrichum was generally present in this region at this time, as shown by our finding fungus-covered bugs in corn shocks and in stubble two miles northeast of Farina, and in similar situations in corn on the farm of Mr. R. H. Smith, four and a half miles east of the city. The fungous growth on the bugs found at the latter place was fresh, but the disease had evidently been present in the field for some time past, as traces of old material were easily detected on the ground, in corn shocks, and in the stubble. Mr. Smith said that no infected bugs had been distributed in the neighborhood of this field. The occurrence of this disease seemed to be universally spontaneous at this time, and we found traces of it in all the surrounding counties.

Mr. Wells wrote November 20 that the disease was still present in corn (B), and reported having seen many fresh fungus-covered bugs in corn shocks while husking corn at that time.

With all the facts before us concerning the interesting occurrences upon this farm, we cannot say that our experiment was successful from the economic point of view, for the muscardine outbreak did not reach its maximum until after the corn had passed the growing season, and it was therefore of no practical use in protecting the crop from the ravages of the chinch-bug. Neither can we say that it was certainly due to the artificial distribution of infected specimens, as the fungus was present here when the first lot of dead chinch-bugs was distributed. (See No. 55.) We must also note that an innumerable host of chinch-bugs remained in the corn in a perfectly vigorous condition during the entire dry period, which included the latter part of June, all of July, and a greater part of August; and that the muscardine fungus apparently disappeared with the advent of this dry weather, not attracting attention again until early in September, after the fall rains had set in, more than a month and a half from the time when the last infected bugs were distributed. Myriads of pupæ and full grown chinch-bugs were present, indeed, in the very midst of the disease in September, and remained apparently healthy and vigorous until winter came on. The ratio of insects dead with muscardine to the live ones present in the field was insignificantly small to the last.

We were also in doubt whether the occurrence of the fungus on farms adjacent to that of Mr. Wells is to be attributed to its spread from his premises, especially as we found it early in October (from the 6th to the 13th) generally prevalent in the counties of Marion, Effingham, Clay, Jasper, Richland, Cumberland, Bond, Morgan, Sangamon, and Champaign. It seems quite possible, indeed, that its appearance on the Wells farm itself was due to the conditions that favored its general development at this time throughout the greater part of Southern Illinois.

Finally, we have no really positive assurance that its growth and spread on Mr. Wells's farm was even hastened by his wholesale and persistent distribution of dead bugs, for the fungus was quite as abundant at the same time in far distant places, where only a few infected insects had been distributed (see No. 77), and in still others where no disease whatever had been artificially introduced (No. 73). It was almost entirely absent in other distant localities where large quantities of both cultivated material and infected insects had been scattered. (Nos. 63, 64, 65, 66, and 67.)

No. 58. This is also a farmer's field infection experiment, the last of the series conducted on the Wells farm. June 10 Mr. Wells placed part of the material taken from his contagion box (No. 56) on that date in the northwest corner of oats (C), where chinch-bugs were very numerous, having come from wheat on the opposite side of the road. The material, about one third of a quart, was scattered over the ground between the drill rows, covering a strip five or six feet in width by four or five rods in length (see heavy dotted lines on Plate I). A second distribution, similar to the above, was made June 20, of several hundred chinch bugs, dead with muscardine, taken from the same box (56).

No traces of the fungus was found in this field June 25, and Mr. Wells reported that no disease was present there July 17, when the oats were cut, although live chinch-bugs were everywhere abundant in the west half. Mr. Johnson carefully searched the stubble and grass along the road September 19, but found no insects dead with disease; in fact, the bugs had entirely abandoned the field, except a few adults and pupæ feeding on an occasional cluster of foxtail-grass. The grass along the roadside was badly infested; but dead insects were very rarely seen. The fungus was quite abundant in corn several rods to the northwest September 28, but the hemipterous insect found at that time, referred to in experiment 57, was the only fungus-covered bug seen in the immediate vicinity of the oat field. The experiment was an utter failure so far as the destruction of chinch-bugs in the oats was concerned.

No. 59. A farmer's contagion experiment conducted by Mr. James Smith on his farm near Farina. About one dozen fungus-covered chinch-bugs from No. 54 were delivered to Mr. Smith June 7 by Mr. Marten. June 8 a box was prepared according to our directions, in which a lot of live chinch-bugs collected from wheat were placed, together with the bugs dead with Sporotrichum. The box was supplied with fresh food and live insects when needed. About June 15 several dozen whitened bodies were removed and placed in wheat (No. 60). The box was kept in good condition until June 27, when it was abandoned by Mr. Smith, who at that time considered the contagious-disease method of "no account in checking chinch-bug ravages," and resorted to the furrow method for the arrest and destruction of the bugs (see No. 88).

No. 60. A farmer's field infection experiment made by Mr. James Smith, on his farm near Farina, with several dozen bugs dead with the fungus from No. 59, which were placed about June 15 in a wheat field where chinch-bugs were very numerous. June 19, field carefully examined by Mr. Marten. First search made in vicinity of place where infected bugs had been distributed. A few adults found here dead with muscardine, but others also throughout the field in about the same proportion. It must be borne in mind that this same fungus was generally present in this vicinity at this time, being more or less abundant in all fields visited. June 7, as noted under No. 55, it was found in wheat on the Wells farm and on other farms adjoining Mr. Smith's. It is quite probable, therefore, that the fungus of the white muscardine of the chinch-bug was locally present in the wheat where Mr. Smith first placed his material. July 11 Mr. Marten found no traces of the fungus in the wheat stubble or in corn adjoining. The disease practically disappeared on this place during the very dry weather of the latter part of June, the whole of July, and a part of August, and appeared again, in corn, late in September, when it was also generally present throughout this region. Mr. Johnson found several chinch-bugs dead with this fungus in an adjoining corn field on this farm September 18 and 28, but no traces were detected in the wheat stubble adjoining.

No. 61. June 15. A field infection experiment started by Mr. Marten in spring wheat on the University farm (see B. Plate II). A quantity of dead and fungus-bearing bugs, together with a few live ones, all from contagion box No. 54, were scattered on the surface of the ground at the bases of the wheat plants in the second drill row for a distance of several rods, represented at *c–a*, a place where live chinch-bugs were most numerous. Ground very dry, no rain having fallen since June 1, and then only .02 of an inch. Sky clear, temperature 91° Fah.* June 16, slight rain in the afternoon (.23 inch), temperature 82°. June 17, cloudy, rain (.2 inch), temperature 82°. June 18, cloudy, temperature 74°. Examined by Mr. Marten. Live bugs were numerous, and traces of original material still present, but no indication that disease was spreading. June 19, clear and warm, temperature 81°. June 20, light rain in afternoon (.1 inch), temperature 87°. June 21, cloudy, temperature 86°. Examined by Mr. E. B. Forbes. Not the slightest indication that the disease was spreading, only two adult chinch-bugs being found dead with fungus after a long-continued search, and these apparently a part of the original stock. Large numbers of young bugs in all stages, with a few adults intermingled, feeding freely at the bases of wheat plants, but no appearance whatever of the infection among them. June 22, slight rain (.05 inch) in the afternoon, temperature 88°. June 23, cloudy, temperature 90°. June 24, 25, and 26, considerable rain (1.18 inch), with average temperature 82°. June 27, clear, temperature 88°. Examined by Mr. Johnson and myself. Plot closely scrutinized throughout its entire length and breadth. Bugs very numerous, but none dead with fungus. Insects rapidly advancing into adjoining corn (C). This same day all the earth from Nos. 68, 69, and 70 was removed, together with several thousand live bugs and many dead ones (about 100 with the fungus and others without), and all scattered in the vicinity of the first place of distribution. June 28, 29, and 30, clear, with high temperature (average 89°). July 1, light rain in forenoon (.05 inch), temperature 83°. July 2, sky clear, temperature 85°. July 3, forenoon clear, afternoon cloudy, temperature 85°. Experiment carefully examined by Mr. E. B. Forbes. A few dead fungus-covered chinch-bugs found on ground in first drill row, but no others at any point in the field. Every wheat plant badly infested with bugs of all ages, mostly of the last two moults. The first three or four rows of corn adjoining blackened with pupæ, or bugs of the moult just preceding, with an occasional adult, all feeding.

* Temperature taken each day at 2 p. m.

voraciously and apparently vigorous. No trace of disease among them. July 4, 5, 6, and 7, clear and warm, with no rain, average temperature 81°. Wheat cut on the latter date. Crop a complete failure; heads light and grains very small and shriveled; not gathered at all; burned over the following day. Many chinch-bugs destroyed by the fire. Corn badly attacked. Experiment a complete failure so far as the spread of the disease was concerned.

No. 62. A second field infection experiment, made June 18 in the same strip of wheat on the University farm as No. 61, and under precisely similar conditions except that the material used consisted of about three thousand live chinch-bugs thoroughly exposed to infection in No. 54, and liberated by Mr. Marten at the point represented at *b*, Plate II. Examined June 21 by Mr. E. B. Forbes, June 27 by Mr. Johnson and myself, and July 3 by Mr. E. B. Forbes again, but at no time were bugs dead with the white fungus found in sufficient numbers to indicate that the contagion had taken effect. On the latter date, however, half a dozen fungus-covered bugs were found on the ground in the first three drill rows, where the original material had been scattered; otherwise no traces of the disease were seen, either in wheat or corn This experiment, like No. 61, considered a failure.

The five following (Nos. 63–67) are successive field infection experiments made on the farm of Mr. Samuel Bartley, one mile west of Edgewood, in southwest Effingham county, a locality particularly favorable to our purposes, since it was in the midst of one of the worst infested districts of Southern Illinois. These experiments were followed through the season by Messrs. Marten and Johnson, of the office force, assisted by Mr. Bartley on the ground.*

All the wheat fields on this farm, as well as those of the surrounding neighborhood, were closely examined by Mr. Marten June 19. Young chinch-bugs in all stages of development were everywhere abundant, covering the wheat in many places, and a few adults were seen. In all these fields small numbers of chinch-bugs, both young and old, were found dead with the fungus of white muscardine, spontaneously occurring. The ground was rather moist at the time from heavy rains of the 16th and 17th of June, the latest previous rain having fallen May 22. The temperature since this latter date had been uniformly high, the daily record rarely falling below 90° Fah.†

No. 63. June 19, several thousand chinch-bugs from No. 54, some still alive and others dead with the white fungus, were placed on the ground in a small wheat field on the Bartley farm where chinch-bugs were most abundant, the exact location being marked by two stakes driven into the ground. Mr. Bartley kept a record of temperature and rainfall, and examined the field every third or fourth day. June 20, 21, 22, and 23 were exceedingly hot, the average temperature reading for these days deing $96\frac{3}{4}$° Fah. No indications that the disease was spreading, June 24, light rain.

* Mr. Bartley has been for several years a correspondent of the office with respect to the economic entomology of his district. He is a man thoroughly competent by education, temperament, and experience to report upon such matters as were here entrusted to him.

† The temperature observations here reported were made by Mr. Bartley daily between eleven and twelve o'clock.

June 25 and 26, heavy rains and high temperature (average observation, 88°). No dead seen. On the other hand, the chinch-bug injury was increasing rapidly, and some wheat was wilting, with shriveled heads. June 27, temperature 100°; wheat cut on 28th and 29th; dry and very hot, average midday temperature 99°.

Examination by Mr. Marten June 29. Several fungus-covered insects found in drill rows where material was placed, and a few others a short distance away, but as a rule their whitened bodies were no more numerous than before the infection was distributed. Myriads of living bugs in the stubble, but a general movement toward adjoining corn on one side and toward timothy on the other. June 30, a shower; temperature 98°. The average midday maximum for the whole month was 94°. July 1 to 10, very warm and dry, average midday temperature 83½°.

Field examined again by Mr. Marten July 10. Wheat stubble very dry, yet containing many live bugs. The great majority, however, have gone into an adjacent corn field. No dead found in stubble, grass, or corn. The remainder of July hot and dry. Good rain the 18th, and slight shower the 19th. No dead found showing any traces of disease. Corn literally covered in many places. Light rain on 28th and 29th. No dead observed. Very warm on 30th and 31st, average temperature record 92°. Average midday reading for month 88°. First three days of August very warm, with light rain the 3d, followed by a week of extremely hot weather. No dead seen.

Nos. 64 and 65. August 6, a second infection experiment was begun by Messrs. Marten and Johnson in two of Mr. Bartley's fields with material derived from two different sources. The first was about three inches square of a culture on corn meal saturated with beef broth from No. 2 (second remove from larva found April 17), and the second consisted of several hundred chinch-bugs dead with Sporotrichum from No. 68. The corn was badly dwarfed in both fields and literally alive with chinch-bugs. Ground damp, temperature 88°. No trace of the disease detected at this time in these fields or anywhere in the neighborhood.

The cultivated fungus (No. 64) was placed in corn about fifty rods from the spot where the first infection (No. 63) had been introduced into wheat. A row along a dead furrow was chosen, where the corn was stunted and literally covered with chinch-bugs. The culture material was cut into small fragments and dropped into the midst of the bugs behind every sheath of twenty-nine hills, the position being carefully marked by cutting away the tassels from the hills at either end.

The infected bugs (No. 65) were distributed in an adjoining corn field thirty-nine rods from the wheat and fifty rods from the preceding distribution (No. 63). Condition of corn about the same as in the foregoing (No. 64). Fourteen hills on the south end of the thirteenth row, counting from the west side, were treated and marked as above.

The weather continued dry and hot for the next four days, the average midday temperature being 97½°. August 11, heavy rain, accompanied by extremely hot weather, the thermometer registering

100°. Both fields critically examined by Mr. Bartley, but no dead bugs seen and only an occasional trace of the original material found. Examined again on the 17th, immediately after a slight shower. No fungus found. Corn in bad condition; ears shriveled and shrunken. The high temperature continued, the noonday average from the 12th to the 17th, inclusive, being 92°, and that for the month being 93°. Light rains on the 23d and 24th. Live bugs on the increase; much corn fallen down. No dead bugs, and no indication that fungus had spread. September 4, very heavy rain, followed by high temperature. Fields very carefully examined by Mr. Johnson. Very muddy, and much corn flat on the ground. In such places, especially, the bugs literally covered every stalk. Few adults seen, the great majority being of the first or second moult or pupæ. Only three bugs dead with this fungus found after a long-continued search, and these under fallen corn, on the ground, a considerable distance from the place where the infection material was placed. Only an occasional stalk of the hills originally treated remained erect, the rest being dead and flat on the ground.

No. 66. Conditions being now especially favorable to success, several hundred spore-covered bugs from No. 68 were distributed in this field on the Bartley farm by Mr. Johnson September 4, behind leaf sheaths, and on the ground under the fallen stalks of twenty-three hills which were black with bugs. The location, which was about twenty-five rods from that of experiment 65, was marked as before. September 7, no indication that the disease is spreading; a few traces of the original material present. Bugs everywhere abundant, and seemingly healthy. September 10, ground still damp, and corn covered with bugs, but none dead with fungus. September 18, similar report.

No. 67. September 7. A second lot of cultivated fungus introduced on this date, material from No. 2 having been sent to Mr. Bartley, who placed it, according to directions, in a one-acre strip of late corn near his house, about eighty rods from the other experimental fields. The chinch-bugs had accumulated in great numbers in this late-planted patch. Seventeen hills of the seventh row, in the southwest corner, were thoroughly treated, as in No. 66. The ground was quite damp, and September 12 a heavy rain fell, followed by extremely hot weather. No dead bugs seen at this last date, but traces of infection material present behind leaf sheaths and on the ground among the bugs. September 16, light rain; corn beginning to wilt from chinch-bug attack; not a single dead insect seen; a little culture material still present.

September 18, Mr. Johnson carefully examined the Bartley farm, and found only a single fungus-covered insect in the last-mentioned field. No traces of the cultivated material. Corn about all dead, a large proportion of it being flat on the ground. Corn in adjoining fields all dead in the immediate vicinity of the places where infection experiments were made, and only six bugs dead with the fungus found after long-continued search. The drooping tassels, and the dirty brown, ragged leaves hanging close to the dwarfed stalks of the remainder, gave to the whole neighborhood an aspect of desolation. In some places the bugs still blackened the stalks but there was a general movement toward an adjacent meadow, in which considerable damage had already been done. Observations made at later visits did not disclose any fungus-covered insects on this farm, and we must therefore class this series of experiments, Nos. 63–67, as absolute failures.

The four following (68–71) are parallel laboratory contagion experiments, conducted at Natural History Hall in large covered wooden boxes, each six feet long by three wide and six inches deep, supplied with a layer of dirt half an inch deep, freed from leaves and rubbish and thoroughly moistened, the bottom of each being finally covered with a layer of fresh green oats, or the stalks and leaves of corn, for food. Each box was supplied with fresh food and live insects as circumstances required, usually every second or third day. The period of operations extended from June 22 to September 20, during which time a sufficient quantity of infected insects was taken out to supply nearly two thousand applicants throughout Southern, Central, and Northern Illinois, as well as large quantities for use in our own experiments.

No. 68. June 22, a part of the contents of 54 were transferred to this box, together with a large quantity of live chinch-bugs from the field. Everything was thoroughly moistened and the box closed by means of a tight-fitting cover, screwed down, the cracks being afterwards pasted up with narrow strips of paper. June 25, found no very considerable development of the fungus. Large numbers of bugs dead which showed no appearance of the infection. Ten of these crushed in water on a slide and examined microscopically contained no fungus mycelium. One lot taken from earth at this time showed no traces of the disease; while several others taken from corn leaves were everywhere penetrated with mycelial threads of some kind of fungus. Dead insects removed and placed on damp sand for further observation. Spoiled food removed, and fresh oats introduced. June 26, quite a number of fungus-covered bugs picked out from food and from surface of dirt; fresh food supplied and more live insects. June 27, box in bad condition; all the earth, food, and insects removed. Box cleaned and re-stocked with fresh dirt, food, and live insects. Several of the whitened bodies taken out were returned to the box. The old material, dirt, food, insects and all, scattered in wheat (experiment 61). June 28, food renewed and live chinch-bugs introduced. June 29 and 30, fresh food supplied.

July 1, box in very bad condition; considerable mold on the dirt, and many bugs covered with Aspergillus. Comparatively few covered with Sporotrichum. All the material removed, box washed out with soap and water, thoroughly burned over by means of a Bunsen burner, and wet with alcohol and burned out the second time. The bottom covered with moist sand about half an inch deep, fresh food introduced, re-stocked with live insects, and infected with fungus-covered bugs collected by Mr. Marten from fields at Odin June 22, and at Shattuc June 23. July 2, no appearance of the fungus. July 3, in good condition, but no fungus developing. Fresh food and live insects from reception box introduced. July 4, very clean and free from mold; very little fungus present; growth not rapid; food changed. July 5, fresh food and live insects added. Anguillulids noticed in abundance in the earth. July 6, a few chinch-bugs with Sporotrichum. Fresh food and live bugs introduced. July 8, no bugs with fungus seen. Box in clean condition. Four cicadas, dead and well covered with this same fungus, collected at Mahomet by Mr. E. B. Forbes, were broken up and the fragments distributed along the sides and corners of the box where live chinch-bugs were most numerous. July 10, boxes overhauled and cleaned and fresh food and more bugs introduced from reception box. A small number of insects dead with the fungus seen. July 11, very little Sporotrichum seen. Box in good condition. Fresh food added. July 12, fresh food introduced. Box in fair condition. July 13, about as yesterday. July 14, fungus scant; fresh food. July 16, three or four bugs with fungus seen; fresh food and live bugs introduced. July 17, no fungus found. Part of the food changed. July 18, very little fungus seen. Fresh food and more bugs introduced. The amount of water used in box increased.

July 19, about half a dozen bugs dead with the fungus. A fourth infection, coming from No. 11, a culture on agar, was introduced at this time. July 20, but little fungus seen. Slight mold on earth. Spoiled food removed. July 21, box overhauled and fresh food introduced. Fungus about as yesterday. July 23, five or six bugs with Sporotrichum seen. The box contains less mold than any of the others (69, 70, and 71) and fewest fungus-covered insects. More live chinch-bugs from reception box added. July 25, overhauled and food renewed. Only about half a dozen fungus-covered bugs seen. Many anguillulids were found quite abundant on bugs dead with and without the fungus, also on the culture medium. A piece of this material upon which both Sporotrichum and Aspergillus were growing was washed and found to contain a considerable number of anguillulids, both dead and alive, confined principally to the surface, or slightly imbedded in the softer and somewhat decomposed spots. July 26, Sporotrichum very scarce. July 27, transferred contents, except sand, dead insects, and a few live bugs, to No. 69. Very little fungus seen. July 30, fungus greatly increased, 165 insects dead with this disease removed. Sand and interior of box thoroughly wet. July 31, quite a number of dead bugs have a fresh fungous growth appearing. A few mites seen.

August 1, seventy insects dead with Sporotrichum removed. Large numbers of chinch-bug eggs found on the sand and on the older corn leaves. Young chinch-bugs, recently hatched, had been noted here for several days. A considerable number of young insects also present. All the sand removed, box scraped and brushed, allowed to stand until nearly dry, then wet with alcohol and burned out. A layer of fresh earth from half to three quarters of an inch deep placed in bottom and cultivated fungus on agar re-introduced. The garden soil was takeh from five to twelve inches below the surface, and was free from rubbish. August 2, all the live chinch-bugs in No. 70 placed in this box. August 4, large number of dead insects, but no fungus seen. Box in good condition. Fresh food introduced. August 6, many bugs dead with good growth of fungus and many others without it. Both Aspergillus and mites in small numbers on culture material. Food renewed. August 9, a large number of dead insects developing Sporotrichum freely. A very few mites and some Aspergillus found on the culture material, much of which was taken out of the box. Food renewed. Several anguillulids found on dead insects in the dirt. August 11, bugs dead with the white fungus on the increase. Aspergillus also present in considerable quantities. A few mites seen on culture material. Anguillulids very abundant, filling the body cavities of insects dead for a considerable length of time. Chinch-bug eggs very abundant on the culture material, some apparently about ready to hatch. August 15, condition of box about the same as when last examined. Sporotrichum still present in considerable quantity. August 18, amount of fungus about the same. Fresh food supplied, box thoroughly moistened. August 22, many adults and a few young dead with Sporotrichum, and several covered with Aspergillus. Still another greenish fungus was present on several bugs. Eggs hatching by thousands in this box. Mites increasing, and anguillulids still present in small numbers. Fresh food supplied. August 25, a considerable number of insects dead with Sporotrichum. Aspergillus seen in small quantities. Live bugs, mostly adults, quite numerous. A few young seen. Fresh food supplied.

September 3. Sporotrichum still quite abundant. Several hundred whitened bodies picked from the surface of the earth and used for experimental purposes by Mr. Johnson at Edgewood and Odin, September 4 and 5 (see Nos. 66, 73, and 74). A few live bugs still present. Fresh food introduced. September 16, box overhauled and fresh food added. About as many fungus-covered bugs as on last date. About fifty dead with muscardine removed and used for field infection experiment at Odin September 19 (see No. 73). Fresh food introduced. September 20, final overhauling. Several hundred whitened bodies picked out, which were distributed by Mr. Johnson to farmers in the south-central part of the State early in October. Only an occasional live insect seen. Box discontinued.

No. 69. June 23, a second contagion box, precisely similar to No. 68, stocked with a large quantity of live chinch-bugs received from correspondents. The infection introduced was from No. 54. Examined June 26; picked out a few fungus-covered bugs and added fresh food and chinch-bugs. June 27, all the material, dirt, bugs, and food removed and scattered in wheat (61), except a few whitened bodies reserved for re-stocking the box. Box thoroughly cleaned. June 28, fresh food supplied and a considerable number of live bugs introduced with the fungus-covered bugs removed yesterday. June 29, fresh earth introduced, and cultivated spores on agar, from No. 11, added.

July 1, very bad condition; earth covered with mold and many dead insects enveloped in Aspergillus. All the contents removed and box thoroughly disinfected. Re-stocked with fresh earth, fresh food, and live bugs. Infected with a number of fungus-covered insects collected by Mr. Marten from fields in the vicinity of Odin (June 22) and Shattuc (June 23). July 2, fresh food added. July 3, food and an additional lot of bugs introduced. Box in good condition, but no muscardine fungus. July 4, fair condition, but little Sporotrichum. Food changed. July 5, about the same as yesterday, except that many anguillulids were seen. Fresh food and more live bugs added. July 6, a little Sporotrichum present, but not so abundant as in No. 70. Mold still growing on earth. Fresh food and live insects introduced. July 8, a few bugs dead with the fungus removed, but the yield was very poor. Two cicadas dead with this same white fungus, from same source as those used in No. 68, were broken up and distributed along the sides, and cultivated fungus on agar from experiment 11, was scattered over the surface of dirt through the middle of the box. July 10, a little Sporotrichum present. Box cleaned, fresh food supplied, and live bugs from reception box introduced. July 11, box overhauled and very little fungus seen. Fresh food introduced July 12, in fair condition; fresh food added. Anguillulids present in small numbers. Many bugs dead, but show no traces of the fungus on their bodies. Attempts to develop Sporotrichum on these bugs by placing them on damp sand proved failures. July 13, condition about the same as yesterday. July 14, Sporotrichum scant. Box put in good condition. Fresh food supplied. July 16, only three or four fungus-covered bugs seen. Molds not so bad as formerly. Fresh food and live insects from reception boxes added. July 17, half a dozen fungus-covered bugs removed. Part of the food changed. Box in fair condition. July 18, very little fungus seen. Fresh food and more live bugs introduced, and the amount of water used in moistening the box increased. July 19, four or five bugs with Sporotrichum. Enough live insects taken out to fill 187 pill boxes, which contained also cultivated Sporotrichum (from No. 2) for distribution. Box in good condition. July 20, but few fungus-covered bugs seen. Spoiled food removed. Little mold present. July 21, fungus about as yesterday. Fresh food introduced. July 23, Sporotrichum not very plentiful. A few bugs dead with the disease found on and in the earth. One hundred and forty-four pill boxes filled with live insects and cultivated material from No. 2. More live bugs added. July 24, small number of bugs with Sporotrichum seen. July 25, box overhauled and food changed. July 26, white fungus very scant. July 27, very little Sporotrichum seen. No anguillulids found in earth or on dead insects. The contents of No. 68, except sand, dead bugs, and a few live insects, were transferred to this box. July 28, few fungus-covered bugs seen. Food changed. July 30, Sporotrichum increasing, but not abundant. Aspergillus also increasing. Anguillulids present in small numbers. Mites numerous on earth, but not abundant on dead or live insects.

Fresh food introduced. July 31, about fifty bugs dead with Sporotrichum. Many insects with Aspergillus also. Moderate number of mites on dead chinch-bugs and decayed vegetable matter. Anguillulids present on dead bugs and dead coccinellid. Fresh food supplied—about one-half the quantity heretofore used.

August 3, final overhauling and cleaning up. Bugs dead with Sporotrichum estimated at about two thousand; many of them pupæ, mainly on the surface of the dirt. Most of the hidden ones were under clods and loose lumps of earth. Quite a number of chinch-bugs were found dead in copulation, in most cases both sexes being infected with the white fungus. Occasionally, however, only one of a pair was dead or visibly diseased, the other being still alive, but unable to free itself. Two instances were noted where one of each pair was dead and covered with Aspergillus, while the other showed no growth of any kind. Mites still present, but considerably less numerous than before. Live chinch-bugs were not abundant, those remaining being mostly adults, with very few pupæ, young of the first and second moult, and numbers of eggs. Box discontinued.

No. 70. June 23, a third box, similar to Nos. 68 and 69, was stocked with food and large numbers of chinch-bugs received from correspondents, but not infected. June 27, thoroughly overhauled; earth supplied; new food and more live bugs introduced. Infected with fungus-covered bugs from experiments 68 and 69. June 28, food renewed and more live bugs added. June 29 and 30, fresh food introduced.

July 1, mold on surface of earth, box in very bad condition. Aspergillus present on several dead bugs. Comparatively little Sporotrichum. Box thoroughly cleaned and disinfected; earth renewed, fresh food added, and live insects introduced. July 2, no fungus seen. July 3, in good condition, but no Sporotrichum seen Fresh food and more bugs introduced. July 4, in fair condition. A few insects with fresh fungus growth on their bodies. Food changed. July 5, condition about as yesterday, except that anguillulids were noticed quite abundant in earth. Food changed and more live insects added. July 6, white fungus more abundant than in experiment 69. Mold on dirt still spreading. Fresh food and more bugs added. July 8, a few chinch-bugs dead with white fungus removed. Earth stirred to destroy mold. Box in fair condition. A second infection introduced. Two cicadas from same source as those used in Nos. 68 and 69, were broken up and distributed over the surface of the dirt, along the middle of the box, and a quantity of cultivated material from No. 2 was distributed around the sides. July 10, a few fungus-covered bugs removed. Dirt contains much mold. Aspergillus less abundant than previously. Box cleaned up and fresh food introduced. July 11, very little fungus seen. Fresh food added. July 12, little Sporotrichum present. Anguillulids seen in dirt. Many bugs dying, but without developing Sporotrichum. Fresh food introduced. July 13, about same condition as yesterday. July 14, Sporotrichum scant, but more abundant than in Nos. 68 and

69. Fresh food added. July 16, thirty-six fungus-covered bugs picked from surface of dirt, and afterwards returned. Molds not so bad as formerly. Fresh food and more bugs from reception box added. July 17, no fungus of any consequence present. Spoiled food removed. July 18, very little Sporotrichum seen, but more abundant than in other boxes (68, 69, and 71). Food changed and amount of water used in the box increased. July 19, fungus more abundant than in 68 and 69. Box in good condition. July 20, very few fungus-covered bugs seen. Removed enough live bugs for three hundred pill boxes, with cultivated fungus (from No. 2), for shipment. A little mold present on earth. Old food removed. July 21, fungus about as abundant as yesterday. Box in good condition. Fresh food introduced. July 23, few bugs with fungus seen. One hundred and forty-four pill boxes filled with live insects and cultivated fungus from same source as above, and prepared for shipment. Large number of live bugs from reception box introduced. July 24, fungus-covered bugs more abundant, but not numerous. Anguillulids present on dead chinch-bugs. July 25, overhauled and food renewed. July 26, Sporotrichum very scant; the living bugs from experiment 71 transferred to this box. Anguillulids found in earth and on corn leaves in small numbers. July 28, but few bugs with Sporotrichum seen. Fresh food introduced. July 30, number of bugs with fungus not great. Aspergillus on the increase. Mites abundant on earth. Anguillulids present on dead pupæ and adults. The worms were present on a dead pupa which contained an apparent mycelial growth of the white fungus. Two adults, dead and badly decomposed, contained them in considerable numbers. July 31, about fifty insects dead with the white fungus seen, but growth very poor, in most cases being quite inconspicuous. Mites very abundant on the corn, especially where the sap was exuding. A few were seen on dead chinch-bugs behind corn leaves. Anguillulids were also seen on dead bugs in similar situations. Old food removed, and about half the quantity of fresh food usually introduced added.

August 2, two hundred and eighty-one fungus-covered insects removed; among them a pair copulating, the female being dead, with a short mycelial growth about the thoracic region, while the male was still alive, quite active, and showed no signs of distress or irritation. Chinch-bug eggs and young were abundant. Ten blow-fly larvæ were seen. Mites very abundant, sometimes accumulating in great numbers on the leaves. Box finally overhauled; everything removed and transferred to No. 68.

No. 71. June 26, the fourth large box was supplied with earth, and stocked with live chinch-bugs and fresh food, but no infection. June 27, fresh food introduced. June 28, food renewed and a lot of live bugs added. Infected with cultivated spores on corn meal and beef broth (from No. 2). June 29, fresh food introduced. July 1, in fair condition. Cleaned up. Fresh food and more live insects added. July 2, very little Sporotrichum seen. A little mold on the earth. Fresh food introduced. July 3, enough fungus-covered bugs removed to make up forty-nine boxes for correspondents. Little mold on earth. More live bugs added. July 4, fungus quite abundant, the whitened bodies of the insects being most abundant just beneath the surface of the earth. Material for thirty-eight packages removed. Earth in box stirred up to destroy molds. Fair condition. Food changed. July 5, condition about as yesterday, except that a few anguillulids were seen in earth. July 6, a few fungus-covered bugs present. Molds still developing on earth. Fresh food and live insects added. July 8, very little Sporotrichum seen. Box in very bad condition. Aspergillus quite abundant on dead bugs, and molds common on the earth. Blow fly larvæ very numerous. Food changed and live bugs introduced. July 10, only slight traces of muscardine. Aspergillus seems less abundant. Molds still present. Fresh food added and more chinch-bugs from reception box introduced. July 11, few bugs dead with Sporotrichum. Box in fair condition. Fresh food and more live insects added. July 12, in fair condition. Anguillulids present on earth. Many bugs dying without developing any sort of fungous growth Fresh food introduced. July 13, condition about the same as yesterday. Anguillulids present in small numbers. July 14, Sporotrichum very scant. Food changed. July 16, only two insects dead with muscardine seen. Molds on earth not so bad as formerly. Fresh food and an additional lot of bugs from reception box introduced. July 17, no Sporotrichum of any consequence seen. Fresh food added. July 18, white fungus very scant. Fresh food added. Amount of water used in moistening box increased. July 19, a greater number of insects dead with muscardine than were seen in experiments 68 and 69 on this date, the number dead, however, being about equal to those in No. 70. Box in good condition. July 20, very few fungus-covered bugs seen. Bad food removed. Slight traces of mold on earth. July 21, amount of fungus about as yesterday. One hundred and thirty-two pill boxes filled with live bugs and cultivated material (from No. 2), and prepared for shipment. Box thoroughly overhauled and fresh food introduced. July 23, more bugs from reception box introduced. July 24, bugs with Sporotrichum few in number. Anguillulids quite plentiful on dead insects. July 25, box overhauled and food renewed. July 26, white fungus very scant. A quantity of living bugs transferred from this box to No. 70. Anguillulids found quite abundant on the earth. July 30, final overhauling. No Sporotrichum found. Many dead insects covered with Aspergillus. Mites very abundant on earth, and their eggs found on a dead chinch-bug enveloped in a growth of Aspergillus. Box discontinued.

No. 72. An experiment begun June 1 to test the direct effect of moisture upon chinch-bugs in confinement. A number of specimens from Tonti, in Southern Illinois, which had not been exposed to fungous infection, were placed in a Riley breeding-cage, the top of which was afterwards covered with glass to prevent evaporation. This cage sat in a metal pan, the bottom of the cage being filled with earth. Water was poured into the pan outside of the cage, and kept standing there continuously to insure the saturation of the earth and the air inside the cage.

June 2, water stood in drops on the sides of the cage and on corn and grass within. June 4, no losses among the chinch-bugs. June 9, many of the bugs dead, but with no trace of fungous growth. June 13, adults now all dead, but with no appearance of disease; young still in good condition; earth saturated and moisture standing in drops on plants and all over the inside of the breeding-cage. June 15, only a very few young bugs left alive, none having shown fungous disease at any time. Between this and July 3, those remaining died; and at the latter date, when the cage was overhauled, no growth of a fungous parasite had appeared on these specimens.

The two following (Nos. 73 and 74) are successive field infection experiments conducted by Mr. Johnson near Odin, in Marion county, a district especially favorable for experimental work, each being followed up by repeated visits, from August 7 to October 6.

No. 73. August 7, several hundred fungus-covered bugs from No. 68, were placed behind leaf sheaths and on the ground in a field of late corn on the farm of Mr. W. G. Ferguson, Sr., one mile north of Odin. The spot chosen was especially favorable to the growth of the white fungus, being along a dead furrow in a low, damp place where the corn was much dwarfed and completely covered with chinch-bugs which had come largely from an adjoining wheat field. No fungus-covered insects were seen here at the time.

Every hill on the west end of the twenty-third row, counting from the south side, was treated with spores of muscardine for a distance of thirty paces. The tassels were cut, marking the east and west boundaries. Chinch-bugs both young and old, were very abundant; adults were copulating, and young just past the first moult reddened the stalks.

This field was examined by Mr. Johnson September 5. Very heavy rain had fallen the day before, and the field was very muddy. No traces of disease were found, except a single fungus-covered insect behind a leaf. The corn was nearly destroyed by the chinch-bugs, and flat on the ground in many places, especially in that part of the field where the infection material had been distributed. Only five or six stalks of the hills treated remained standing. Stalks flat on the ground and not dead were literally covered with live bugs. Other parts of the field, where the corn was most vigorous, and where the bugs were least abundant on our former visit, were now overrun with the chinch-bug hosts; in one place about two thirds of a pint were collected from two hills, by jarring and shaking them over a cloth spread on the ground. The insects were very active, and apparently in a healthy condition.

At this date (September 5) Mr. Johnson placed a second lot of infected bugs from experiment 68 in this field, where the conditions were especially favorable. The ground was very wet and the corn much lodged and covered with chinch-bugs. About one hundred bugs dead with the white fungus, were scattered behind corn leaves, about forty rods from the place where the first infection material was introduced.

September 19, Mr. Johnson carefully examined this field again. Corn had been cut, where it was worth saving at all, and shocked. The bugs were thickly concentrated in the shocks, but no traces of muscardine were seen among them. The insects were still very abundant in the stubble. The corn in many places was as flat on the ground as if a roller had gone over it, and in such places every stalk was blackened with bugs. A third lot of chinch-bugs, about fifty in all, dead with Sporotrichum from the same source as the others (No. 68), were now scattered over the ground under the fallen corn, at one place about ten rods from the row where the second lot of bugs had been placed. The greater part of the corn on the ground was brown and dead, and there was a general movement of the chinch-bug hordes into late corn in an adjoining field on the west, and into a meadow touching the southwest corner. Considerable damage had been done by the insects to the grass in the latter field, and corn in the former was suffering severely from their attacks. Not a single diseased bug was found in any of these fields at this time.

Examined by Mr. Johnson September 26. Very few chinch-bugs in the stubble. One bug found imbedded in the white fungus. Many insects in the meadow. The late corn in the field adjoining the stubble badly damaged, the attack apparently increasing. No traces of disease seen in this field. Bugs seemingly vigorous and healthy.

The final visit of the season to this locality was made by Mr. Johnson October 6. At this time the late corn in the field last mentioned in the preceding paragraph had been cut and shocked about a week, and the ground planted in wheat. The bugs had accumulated in enormous numbers in the shocks. Half a dozen fungus-covered insects were taken from shocks in this field at various places, and several were taken from grass in the adjoining meadow, where the chinch-bug attack was still spreading. A dozen or more whitened bodies were taken from shocks and under fallen corn in the field where the infection had been distributed, but the fungus was nowhere abundant, and long-continued search was required to find even a single specimen. A few live chinch-bugs, mostly adults and pupæ, were still present in the stubble, and bugs in the same stages were quite abundant in the shocks. Corn in both these fields was a complete failure, and was saved for fodder only. Chinch-bugs dead with the white fungus were found in all fields examined in this county at this time, but only in two places (see Nos. 57 and 76) were they at all common, and even here the live bugs outnumbered the dead many thousand times. This experiment for the introduction and increase of the fungus by artificial means was to all appearance a complete failure.

No. 74. August. 7. The second of this series of experiments was begun in a twenty-acre corn field (B, Plate IV.) owned by Mr. Silver, of Cincinnati, Ohio, and planted by Mr. Frank Robinson, of Odin. This farm is about a mile and a half north of Odin, between the Ferguson farm on the south (No. 73) and the Hurd and Robinson farms on the north (Plate IV). The field was very dry and dusty; the corn thin, short, and very poor. Chinch-bugs just past the first moult covered nearly every stalk. A few adults were seen copulating. No traces of the fungus disease were seen.

A row of dwarfed, sickly-looking corn along a dead furrow about the center of the field, thickly covered with bugs, was selected as a suitable place for the introduction of the infection. A piece of culture material from No. 2, about two inches wide by four inches long, containing a profuse growth of Sporotrichum, was cut into small fragments and placed among the bugs behind the leaves of every hill, for a distance of fifty paces, the spot being marked by clipping the tassels from the hills at either end.

Examined August 18 by Mr. Johnson. No fungus-covered insects found. Some of the culture material still present. Corn in very bad condition and flat on the ground in many places. Chinch bugs cover the corn throughout the field. Foxtail and other grasses literally alive with the insects. Weather very dry and hot.

Second examination September 5, immediately after very heavy rain. Field very muddy. No traces of the infection material visible, and no bugs dead with the fungus seen. Corn crop an utter failure. Chinch-bugs seem to be increasing in numbers. Selected another row along a dead furrow, about five rods from the first, and distributed about one hundred fungus-covered bugs from experiment 68 behind the leaves for a distance of seventy-three paces, and marked as before.

September 19, not a single insect dead with the white fungus found in this field after an hour's diligent search. Corn about all dead. Chinch-bugs still very abundant, but many going into meadows on the north and east. Few adults seen flying.

September 26, about as before, except that the corn is all dead and chinch-bugs less numerous. No dead seen, and not a trace of the fungus found. Chinch-bugs very abundant in the adjoining meadows, and considerable grass killed.

The final visit for the season was made October 6. About one fourth of the corn had been cut and shocked and saved for fodder; the other three fourths was flat on the ground, dead and brown. Chinch-bugs, mostly adult and pupæ, were quite numerous in the shocks, and on the fallen corn throughout the field. Half a dozen bugs dead with Sporotrichum were picked up on the ground under a corn shock about two rods from the place where the last lot of infection material had been introduced, and a few others were found at various points in the field, under shocks and fallen corn, but this was all. The presence of the fungus on chinch-bugs in this field at this time did not seem to have any connection with that distributed August 7 and September 5, since the disease was found more or less prevalent in all fields visited in this neighborhood at this time. As the white muscardine did not spread from the centers where the infection was introduced, and as the chinch-bug hosts continually increased, remaining in a vigorous and perfectly healthy condition in its very midst, the experiment is regarded as a complete failure.

This description should be read, however, in connection with that given under No. 76, relating to a considerable outbreak of chinch-bug muscardine on a farm immediately adjoining this on the north.

No. 75. This is a farmer's field infection experiment made by Mr. Frank H. Robinson on his farm (the right hand third of Plate IV.), about two miles north of Odin. August 7, several pieces of culture material containing a profuse growth of the white fungus, from No. 2, were placed in Mr. Robinson's hands by Messrs. Marten and Johnson, and directions given for its distribution. August 8, two small plats of corn, represented on Plate IV., at C and D, thickly covered with chinch-bugs, were chosen, and the infection material scattered along the north side next the orchard, behind the leaves and on the ground at the bases of the stalks where the insects were most abundant.

September 5, examined by Mr. Johnson. Corn all dead in plat represented at D. Chinch-bugs still very abundant on the dead brown stalks and leaves. No traces of the infection material found, and only two bugs dead with this fungus were seen; and these were taken from under a clod on the ground, which was very wet from recent heavy rains. About the same condition was noted in plat C, except that a few traces of the old culture material still remained on the ground at the bases of a few stalks, and that no fungus-covered bugs were seen. Chinch-bugs were present in small numbers in all the meadows bordering the field containing this corn. In a twenty-two acre field north of the house, represented at E, the corn was completely destroyed by their attacks, and nothing green remained. The bugs were everywhere abundant, and almost completely covered the ground in many places, but there were no traces of fungous disease. Grass in the meadow adjoining on the south was slightly damaged.

September 19, a few live bugs, mostly adults and pupæ, were seen in the stubble at C and D, but no traces of Sporotrichum were found. The insects were still present in the surrounding meadows. The corn ground (E) had been planted in wheat, and only a few bugs remained in the field. The attack had greatly increased in the meadow to the south, and considerable grass had been killed. No traces of the white fungus seen on this place at this time, September 26 and October 6, similar report made by Mr. Johnson, except that a few fungus-covered bugs were found in the meadow south of E on the latter date. The experiment is classed with 73 and 74 as a total failure.

This description should be read, however, in connection with that given under 76, relating to a considerable outbreak of chinch-bug muscardine on a farm immediately adjoining this on the west

No. 76 This is the second of the three exceptional cases of spontaneous muscardine, referred to above. It appeared on the farm of Mr. Silas Hurd, about one and a half miles north of Odin, in the corn field marked A, Plate IV. This field of forty-nine acres was planted early and grew rapidly for a time, but then came practically to a stand on account of incessant chinch-bug attack and the drought which prevailed throughout that region during the latter part of the summer.

The corn was cut and shocked while yet in roasting ears, early in September, in order to save the fodder, and the field was deeply harrowed and planted to wheat. No Sporotrichum had been distributed in this field at any time; but unsuccessful attempts to infect fields had been made, as described under Nos. 74 and 75, on the Robinson and Silver farms at distances of a little more than a quarter of a mile away. (See B, C, and D, Plate IV.)

Mr. Johnson examined this field October 6, and found the white fungus quite abundant in all the shocks. One hundred and fifty-two dead chinch-bugs imbedded in it were collected in a few minutes from a single shock at *a*, and every shock examined in the southern and western parts of the field contained fungus-covered bugs in considerable numbers. At *b*, in the northeastern part, it was an easy task to collect several hundred whitened bodies in and under every shock. This part of the field was quite low, and chinch-bugs, mostly adults and pupæ, had accumulated in the shocks in enormous numbers. This was perhaps due to the fact that all green vegetation in the field had been destroyed by the harrow and cultivator, and that the bugs were obliged to congregate in the shocks or to leave the field in search of other food.

Only an occasional fungus-covered insect was found in a field of sweet corn (F) which had been completely ruined by chinch-bugs, and which was not cut at all. Adults and pupæ were still present there, but not very abundant. Bugs were seen in small numbers in all the grass lands surrounding the corn (A); but no traces of the fungous disease were found, with the exception of three or four dead insects taken from grass in the meadow next the road east of A. A few others imbedded in Sporotrichum were found in corn (B), as noted in experiment 74, and several were taken from grass in the meadow west of corn field E, as stated in No. 75.

The fact that this fungous disease was almost totally absent in fields surrounding A, would seem to indicate that it must have been fostered in the latter field by especially favorable conditions. These seem to have been (1) the early cutting and shocking of the corn while it was still green; (2) the destruction of all food throughout the open field, such as grasses of various kinds and the green stubble itself, by harrowing and cultivating; (3) the consequent concentration of the chinch-bug hordes in the shocks; (4) the heavy rains which fell about September 16 and 17, wetting the shocks and thoroughly drenching the chinch-bugs; and (5) the retention of the chinch-bugs in the shocks at a time when their food supply was short, and when the moisture was also sufficient for the germination of any spores of the white fungus that may have been present.

Mr. Hurd wrote the office, November 20, that the disease was still present in these shocks, and that he had collected an abundant supply for use next spring.

No. 77. This is a farmer's field contagion experiment made by Mr. George W. Heth on his farm (see Pl. III.) about five miles west of Edgewood, in West township, in the extreme southwest corner of Effingham county. It is the last of the three exceptional cases of the development of white muscardine in the field, to which reference has already been made.

The material used in this experiment was derived from two original sources; the first, a small number of chinch-bugs dead with Sporotrichum received by Mr. Heth May 15, from Chancellor Snow, of the University of Kansas; the second, similar material sent him early in June from my office, from No. 54 of this series. The fungus-covered specimens received from Kansas were scattered directly (May 15) among chinch-bugs in wheat (see A, Pl. III.) at about the center of the field. The bugs were very abundant at the time, practically covering the wheat everywhere throughout the field. A slight rain fell May 17, followed by heavy storms on each succeeding day until the 20th. The fungus did not seem to spread, and the chinch-bug attack became daily more intense. Dry weather followed until the middle of June, when, according to Mr. Heth's observations, no traces of disease could be found in the field. In the meantime the second lot of specimens above mentioned, derived from No. 54, had been placed by Mr. Heth in a large pasteboard box stocked June 10 in the usual manner for infection purposes, but, according to his somewhat vague statement, without very successful results. Several days afterwards Mr. Heth began to distribute this material in his wheat. "I removed some of the insects from the box," he says, "part of which were white with fungus, every second day, and scattered them over the ground near the center of the wheat field A, where the bugs were extremely thick. These distributions were made in the evening and were kept up for about a week, but the soil was very dry." Rains fell on the 16th and 17th of June, but no traces of muscardine could be found on the 18th, or at the time when the wheat was cut, June 25. The ground was, in fact, in many places almost black with living chinch-bugs at that time, and there was a general movement to the north and east into corn fields adjoining (marked B and C on Pl. III.), the greater number going, however, into field C, where the corn was presently almost completely destroyed. The destructive horde passed thence successively into fields D, E, F, and G, where they continued their ravages until late in the fall.

On September 28, while examining the grass in the orchard F, at the point *a*, Mr. Johnson discovered many dead chinch-bugs on the ground under the stools of grass thickly enveloped in a dense, fresh growth of Sporotrichum. Half a dozen whitened bodies were taken from under a single stool at this point; but for every dead bug collected, several hundred live ones were seen. The fungus-covered insects were about equally distributed throughout F and G, along a line north from *a*; but to the south of this point the dead bugs were not so abundant, while, on the other hand, the live insects were just as numerous. This was perhaps due to the fact that this was the highest portion of the field, and was considerably dryer than at *a* and points further north. The chinch-bugs had spread over about three acres, and had killed all the grass west of the wavy line passing through F and G. The grass was parched and brown, and the victorious chinch-bug hosts were steadily advancing eastward.

A careful examination of the grass west of *a*, revealed the fact that the number of bugs dead with the fungus increased as the sorghum (E) was approached; that is, the number of fungus-covered bugs counted on a given area—one square foot—constantly increased until the point *b* was reached, at which place the greatest numbers were observed, and then gradually decreased, practically disappearing at *c*, as we passed into the corn (D). At *b* two hundred and seventy-one whitened bodies were counted on the surface of the ground scattered over a single square foot. The ground at this point, however, was thickly strewn with sorghum leaves and was quite damp.

Another interesting point observed at this time was the comparative age of the fungus along a line from *a* to *c*. At *a*, as already indicated, the fungous growth was fresh, and in some instances the mycelial threads were but just starting, being but barely visible on the bodies of the dead bugs. As we approached *b*, however, it became evident that the fungus on the insects was of a much older growth. At a point midway between *a* and *b*, bugs dead with the fungous disease were found, from which the spores were not easily detached, while at *b* the spores were easily shaken off, and in most cases the ground where a dead bug had been lying was so dusted with them as to present a whitish, moldy appearance. From *b* to *c* the fungus was of a still earlier growth. Along a dead furrow at the latter point, several dirty whitish, moldy spots on the surface of the ground under a fallen corn leaf or stalk, or other rubbish, was all the evidence that could be found that the fungus had been present.

Comparatively few chinch-bugs dead with the white fungus were found in corn B, C, H, I, and J, not more than half a dozen being taken from each field. Their whitened bodies were perhaps more abundant in corn H along the south side in the immediate vicinity of the meadow G, than in any of the other fields examined. Live chinch-bugs, mostly pupæ and adults, were quite numerous throughout all these fields. All the meadows adjoining corn on this farm were more or less injured from the attacks of the chinch-bug, but little or no fungus was found in any of them except those already mentioned, F and G. Only an occasional live insect was seen in the wheat stubble A, in which the infection had been placed, and in the stubble of oats and wheat south and east of the house.

A dozen or more insects dead with Sporotrichum were found in a corn field belonging to Mr. Wm. Kelley, one mile east of the Heth farm, and several were taken from the surface of the ground under stools of foxtail-grass along the roadside in the immediate vicinity of the same field.

The Heth farm, as well as the surrounding country, was again examined by Mr. Johnson and myself October 10. The fungous attack had not increased in intensity, so far as could be ascertained, in the meadows F and G, but the chinch-bugs had continued their ravages, and the irregular line marking the boundary between the infested area and the remainder of F and G had moved several feet eastward. The whitened bodies of dead bugs could be easily found on the ground by parting the grass at any place west of the division line, and they were quite abundant under leaves and rubbish in the sorghum stubble E, but the growth in this latter place had the characteristic weathered appearance of over-ripeness. In corn D an occasional trace of the fungus could be seen, and several chinch-bugs imbedded in it were found under stools of grass along the roadside between C and D. In corn B the fungus was found in shocks and in the open field in the stubble, but that from the surface of the ground under the shocks was of a much more recent growth than that taken from the open field. An occasional bug dead with this disease occurred on the ground in the uncut corn in the same field.

One mile east, on the Kelley farm, to which reference has been made, chinch-bugs enveloped in the white fungus were found in corn on the ground in low, damp places, under fallen leaves, weeds, grasses, and other rubbish. They were also quite abundant along the roadside under stools of grass, but on the whole the fungus was not so plentiful as twelve days previous, and the growth was comparatively old. In an adjoining wheat field, a considerable number of dead insects were found attached to the blades of young wheat plants, and on the ground between the drill rows. After counting both live and dead chinch-bugs on a given area, it was estimated that about twenty-eight per cent. were dead. Subsequent examination of collected specimens showed, however, that the destructive agent in this instance was the gray muscardine (*Entomophthora aphidis*); but a few dead chinch-bugs from this field, showing no external trace of a fungous growth, developed a profuse growth of the white muscardine when placed on damp sand. This fungus was also found on chinch-bugs in all corn fields examined at this time for a distance of four miles south of the Heth farm, but was nowhere as abundant as on the latter place.

It has been already reported on page 118 that the white fungus of the chinch-bug was very widely distributed throughout adjoining counties at this date, and the general tenor of our observations at this time supports the hypothesis that the Heth outbreak was a spontaneous one, arising under the influence of especially favorable conditions, which were substantially as follows: (1) an abundance of food—wheat, corn, sorghum, and grass, into which the chinch-bug hosts passed successively after each harvest, thus keeping them somewhat concentrated; (2) the appearance of the fungus disease on chinch-bugs along a dead furrow running north and south through *c*, at a time when the destruction to corn was about complete, and when myriads of insects were passing this point, going into sorghum, E; (3) the concentration of the bugs on this narrow strip of sorghum—practically accumulating the chinch-bugs of thirty-five acres on these nine rows; (4) the stripping and cutting of this sorghum at a time when the insects were most numerous, which knocked them to the ground in great masses, where they remained under and among the leaves for several days; (5) the occurrence of a heavy rain September 12, followed by a high temperature, and another heavy rain September 16; and (6) the close proximity of the meadows F and G, into which the bugs passed, and where they remained on the damp ground under the grass.

It thus seems quite probable that this fungous outbreak had little or no connection with the infection material distributed during the early part of the season, but that it was simply a local development, under exceptionally favorable conditions, of the diffuse general spread of chinch-bug disease throughout this whole country at this time.

The three following (Nos. 78–80) are successive farmers' experiments conducted in the counties of Cumberland, Bond, and Clay. Individual reports on these farmers' experiments were not called for, and the report here given for 78 and 79 is based upon a single visit made by Mr. Johnson early in October. No. 80 was visited twice.

No. 78. A farmer's experiment, the original material for which was derived from our experiment No. 54. It was sent from this office June 25 to Mr. Thomas B. Wilson, Sr., Greenup, Cumberland county, and used by him to start a contagion box, according to our circular of directions (see p. 92). This box was kept in operation until late in July, live bugs and fresh food being introduced every other day, and the fungus-covered insects removed each time the box was opened. Several hundred such specimens were distributed during the first two weeks of July at the bases of the stalks and behind the leaves of corn along one side of a field adjoining wheat, in places where the chinch-bugs were most abundant. The ground was very dry, and the experiment was a failure, no trace of the fungus appearing so far as could be ascertained by weekly examinations kept up until late in September. These fields were examined by Mr. Johnson October 9, but no trace of insect disease could then be found, although adults and pupæ of the chinch-bug were still abundant in the corn. The first fifteen rows adjoining the wheat had been completely destroyed, only here and there a stalk standing erect. On this same visit several bugs imbedded in Sporotrichum were taken from corn shocks about two miles from town in another direction.

No. 79. A farmer's experiment, conducted by Mr. W. E. Jackson, of Greenville, Bond county, with material from No. 54.

About a dozen chinch-bugs, received from this office, were placed in a box July 1, prepared according to our directions, with live insects and fresh food, both of which were renewed as necessary, a few whitened bugs being taken out of the box each time that it was opened, and distributed in the corn. July 15, about a hundred fungus-covered specimens were placed behind leaves and on the ground, where the bugs were most abundant, in a field of corn on Mr. A. H. Jackson's farm, a quarter of a mile south of his house. Two similar distributions were made in this field July 28 and August 12. The corn was examined every week, but no indication was found that the disease was spreading, the chinch-bug attack, in fact, increasing steadily week by week. The corn was cut and shocked about September 3, in order to save it for fodder, and the bugs collected in the shocks, where they remained until late in fall. This field was carefully examined by Mr. Johnson October 10. The corn had been thoroughly wet by heavy rains soon after cutting, and the ground was still very wet under the shocks. There was little or no grass in the open field, and consequently very few chinch-bugs. They were quite abundant in the shocks, and numerous in an adjoining meadow, but not sufficiently so to do any appreciable damage. A careful search was made in shocks all over the field, but no traces of the white fungus were found except in four shocks in the northeast corner, and here the greater part of the diseased insects were found in the third shock of the first row on the north, counting from the east. Several hundred chinch-bugs and three beetles (*Coccinella 9-notata* Hbst., *Atænius stercorator*, Fab., and *Epicauta vittata*, Fab.) completely enveloped in the white fungus were taken from the ground and from behind leaves in the shock. Half a dozen chinch-bugs dead with Sporotrichum were taken from three other shocks in the immediate vicinity. The disease was also found in small quantities in corn shocks directly east on the opposite side of the road; and three whitened bodies were taken from a low damp furrow or ditch in the meadow adjoining on the north. A few fungus-covered bugs were found in corn shocks in an orchard near the house, and quite a number were found in shocks and on the ground in low damp places in a corn field one mile east.

Just why the disease should have been so abundant in the single shock mentioned above, and totally absent or nearly so in all other shocks in the field, we will not attempt to explain. Suffice it to say that the infection was distributed along this side of the field, and that all the other shocks in the same row were similarly situated and cut at the same time.

The experiment was a failure, and did not arrest the ravages of the bugs in the least. A part of the fungus-covered bugs collected in these fields were placed in Mr. W. E. Jackson's hands for future experimental purposes.

No. 80. A farmer's experiment, made by Mr. C. M. Filson, Xenia, Clay county, the original material for which was derived from this office. The box was carefully prepared according to our circular of directions (see p. 92), and infected June 20 with about a dozen bugs from No. 54, this series. The box was kept on the damp floor of a cider house. Bugs enveloped in the white fungus were removed every fourth or fifth day, and live insects and fresh food were added as required. This box was kept in active use until about September 1. It was examined by Mr. Johnson September 27, at which time, although the insects were all dead and the food was dried up, it was still in good condition, and about a hundred chinch-bugs thickly imbedded in the muscardine fungus, were taken out and given to Mr. Filson for future use. Several hundred fungus-covered bugs from this box were distributed in corn along the north and south sides of a field on Mr. Filson's farm about July 1, and about ten other distributions were made at regular intervals after a rain or on damp mornings, with bugs from the same source. Chinch-bugs entered this corn from an adjoining wheat field, literally covering the stalks in many places. This field was examined about every third day, but no trace whâtever of the white fungus was detected. As a consequence, this experiment was abandoned, and other measures were taken by the owner to arrest the ravages of the chinch-bug (see No 89). Mr. Johnson examined this field September 27 and again October 6, but did not find a single infected insect. The corn had been cut at the time first mentioned, but the bugs were still quite abundant in the shocks, and foxtail and other grasses along the fences and in low damp spots throughout the field were thickly covered by them.

Several fungus-covered bugs were found by Mr. Johnson September 27 in grass along the roadside more than a mile from Mr. Filson's farm, and again on the Filson farm also during the latter part of November. December 10 Mr. Filson writes: "I could see no effect of the disease on my farm until after the recent rain. At the present time I find chinch-bugs covered with fungus in all the shocks in corn adjoining timber."

ANALYTICAL LIST OF AMERICAN ARTICLES CONSULTED. 1824—1894.

1824.

Cist, Jacob.—Notice of the Melolontha or May bug. (Am. Journ. Sci. and Arts, Aug., 1824, v. 8, p. 269.)

Report of the occurrence of Cordyceps on Melolontha.

Halsey, Abraham.—Remarks on certain Entozoical Fungi. (Ann. Lyceum Nat. Hist. N. Y., Apr., 1824, v. 1, p. 125.)

On a specimen from Gaudeloupe in the collection of the Lyceum of Natural History of New York. On *Sphæria entomorhiza*, Dickson; *S. militaris*, Persoon; and *Isaria sphingum*, Schweinitz. The latter is always found upon the body and wings of sphinges hanging with outspread wings on twigs.

1827.

MITCHILL, S. L.—Views of the Process in Nature by which, under Particular Circumstances, Vegetables grow on Bodies of living Animals. (Am. Journ. Sci. and Arts, June, 1827, v. 12, p. 21.)

Mention of Cordyceps on Melolontha from Virginia and on various exotic insects. General discussion.

1849.

LEIDY, JOSEPH.—[On the Existence of Entophyta in Healthy Animals as a Natural Condition.] (Proc. Acad. Nat. Sci. Phil., Oct. 9, 1849, v. 4, p. 225.)

Account of vegetable parasites of Julus, Passalus, and other animals, including descriptions of the new genera Enterobrus, Cladophytum, and Arthromitus.

LEIDY, JOSEPH.—Description of New Genera and Species of Entophyta. (Proc. Acad. Nat. Sci. Phil., Dec. 25, 1849, v. 4, p. 249.)

Descriptions of filamentous fungi from the alimentary canal of species of Julus and Passalus.

1850.

BROWN, BUCKMINSTER.—[Remarks on a Caterpillar Fungus (*Sphœria robertsii*) from New Zealand.] (Proc. Boston Soc. Nat. Hist., Dec., 1850, v. 3, p. 341.)

LEIDY, JOSEPH.—[Entophyta in Bodies of Animals.] (Proc. Acad. Nat. Sci. Phil., Feb. 12, 1850, v. 5, p. 7.)

Remarks on *Mucor mucedo*, *Achyla prolifera*, and some unnamed species in insects and crayfish.

LEIDY, JOSEPH.—[Entophytes in Insects and Myriapods.] (Proc. Acad. Nat. Sci. Phil., Feb. 19, 1850, v. 5, p. 8.)

Remarks on species of Enterobrus, etc.

LEIDY, JOSEPH.—Descriptions of New Entophyta growing within Animals. (Proc. Acad. Nat. Sci. Phil., Apr. 30, 1850, v. 5, p. 35.)

Description of new genus (Eccrina) and three new species. Remarks on development of Arthromitus.

1851.

LEIDY, JOSEPH.—[Remarks on Parasitism of Insects.] (Proc. Acad. Nat. Sci. Phil., 1851, v. 5, pp. 204, 210.)

Account of culture experiment with fungus of mole cricket. Dr. Leidy remarks that amount of parasitism in insects is influenced by kind of food. Hemipterous insects remarkably free from parasites; those eating decaying substances especially subject to them.

LEIDY, JOSEPH.—[*Cicada septendecim* affected by a Fungus.] (Proc. Acad. Nat. Sci. Phil., 1851, v. 5, p. 235.)

Brief description of spores. Also mention of fungus attacking lamellicorn larvæ and mole cricket (Gryllotalpa).

1853.

LEIDY, JOSEPH.—A Flora and Fauna within living Animals. (Smithsonian Contributions to Knowledge, Apr. 1853, v. 5, Art. 2.)

An elaborate illustrated article on fungi normally inhabiting the alimentary canal of various insects and myriapods.

LEIDY, JOSEPH.—[On a Fungus Parasite of the Seventeen-year Locust (*Cicada septendecim.*)] (Fauna and Flora within living Animals; in Smithsonian Contributions to Knowledge, Apr. 1853, v. 5, p. 53.)

Describes general appearance of parasitic fungus of the seventeen-year locust observed in 1851, which converted the posterior third of the abdominal contents into a mass of spores. Spores described, and portions of mycelium described and figured.

1854.

WYMAN, JEFFRIES.—[Remarks on Growth of Parasitic Fungus (Empusa) upon the Common House-fly.] (Proc. Boston Soc. Nat. Hist., Dec. 1854, v. 5, p. 90.)

1856.

GLOVER, TOWNEND.—[Note on Disease of Caterpillar.] (Rep. [U. S.] Commissioner of Patents for 1855—Agriculture, p. 91.)

Mention of destructive disease among caterpillars of an unknown species in South Carolina.

1858.

GRAY, G. R.—"Notices of Insects that are known to form the Basis of Fungoid Parasites."

"Privately printed by the author. No place of publication given on the title page, but probably London. A general summary with full account of literature of the subject, including American references and good plates reproduced from various sources."—*W. G. Farlow* and *W. Trelease.* (Bibl. Contrib., Libr. Harv. Univ., No. 25, p. 17.)

1865.

KIRTLAND, JARED P.—Pear-tree Blight—concerning Cause and Cure. (Prairie Farmer, July 29, 1865, v. 16, p. 71.)

Brief reference to Cordyceps on Melolontha larvæ.

1867

Shimer, H.—Notes on *Micropus* (*Lygæus*) *leucopterus*, Say ("the Chinch Bug"). With an Account of the Great Epidemic of 1865 among Insects. (Proc. Acad. Nat. Sci. Phil., May, 1867, [v. 19], pp. 75, 234.)

Description of this disease; not at present identifiable.

Walsh, B. D.—A Plant growing out of an Insect. (Prac. Ent. Aug.–Sept., 1867, v. 2, p. 116; Am. Ent. Dec., 1868, v. 1, p. 77.)

On Cordyceps from Iowa. Large numbers of infested white grubs turned up by plow. Writer supposes that the grub has eaten poisonous seed, which has germinated after killing the insect. Hopes that kind of seed may be discovered and sown where grubs are abundant.

1868.

Shimer, H.—Nature's Method of controlling Noxious Insects. (Trans. N. Ill. Hort. Soc., 1867–68, p. 96.)

Reprints article from Proceedings of Philadelphia Academy of Natural Sciences for 1867. Says further that he could not find a single chinch-bug last summer [1867] by diligent search.

1869.

Early S. H. Y.—Fungoid Growths [on white grub]. (Am. Ent. v. 1, p. 92.)

Very common in Virginia. Believed there to produce a poisonous mushroom.

Ratzeburg, J. T. C.—[Fungoid Parasitism of Insects.] (Proc. Boston Soc. Nat. Hist., April, 1869, v. 12, p. 381.)

Letter to Dr. H. A. Hagen quoted. Finds an inverse relation between parasitism by insects and by fungi.

Riley, C. V.—The Periodical Cicada. (First Ann. Rep. State Ent. Mo., 1869, p. 18.)

On page 26, are remarks on enemies of the cicada, with note of Dr. W. D. Hartman on a greenish powdery fungus found within it.

Riley, C. V.—The White Grub. (First Ann. Rep. State Ent. Mo., 1869, p. 156.)

Notes on a Cordyceps infesting the larva of the May beetle, with figure.

Walsh, B. D., and Riley, C. V.—Fungoid Growths. (Am. Ent., Jan., 1869, v. 1, p. 91.)

Publication of, and remarks on, a communication from S. H. Y. Early. Fungoid growths on white grub very common in Virginia, and believed to produce a poisonous mushroom.

WALSH, B. D., and RILEY, C. V.—The Chinch Bug (*Micropus leucopterus*, Say.) (Am. Ent., v. 1, 1869, p. 174.)

Criticise at length Shimer's theory of the disappearance of chinch-bug outbreaks as a consequence of epidemic disease. Express belief that such disappearances are due to direct effect of weather.

1870.

RILEY, C. V.—The Chinch Bug—*Micropus leucopterus*, Say. (Second Ann. Rep. State Ent. Mo., p. 15.)

Repeats in brief (p. 24) criticism of Shimer's theory of epidemic disease of the chinch-bug. (See Walsh & Riley, 2d entry 1869.)

SHIMER, H.—Entomological Notes. (Trans. Ill. Hort. Soc., 1869, p. 275.)

Argues from analogy the probability of the occurrence of contagious diseases among insects.

1872.

MURIE, JAMES.—On the Development of Vegetable Organisms within the Thorax of living Birds. (Monthly Micr. Journ., April, 1872, v. 7, p. 149.)

Mention of fungi as occurring in insects.

PACKARD, A. S., JR.—Second Annual Report on the Injurious and Beneficial Insects of Massachusetts, 1872, p. 4.

Several thousand dollars' worth of silkworms killed at East Bedford, Mass., by imported *pébrine*.

[RILEY, C. V.]—Remarkable Parasitic Fungus. (Sci. American, May 25, 1872, v. 26, No. 22, p. 347.)

Figures a white grub with a Sphæria growing from its anterior end.

F. S. [SNOW?].—[White Grub Fungus commonly found in Kansas in 1869 and 1872.] (Rural World, June 8, 1872.)

1873.

LECONTE, J. L.—Hints for the Promotion of Economic Entomology. (Proc. A. A. A. S., 1873, Pt. 2, p. 10.)

Mentions among checks against insect increase the communication of fungoid disease (like *pébrine* of the silkworm) to other lepidopterous larvæ, and advises experimentation along this line.

1874.

BURRILL, T. J.—[Chrysomelid Larva attacked by a Fungus.] (Colman's Rural World, May 15 (?), 1874, v. —, p. —.)

Cordyceps on a larva resembling that of *Diabrotica vittata.*

BURRILL, T. J.—White Grub in Illinois. (Cultivator and Country Gentleman, Aug. 27, 1874, v. 39, p. —.)

Mention of Cordyceps.

RILEY, C. V.—The Unadorned Tiphia or White Grub Parasite: *Siphia inornata*, Say. (Sixth Ann. Rep. State Ent. Mo., p. 123.)

Mention of *Torrubia militaris* (possibly *T. cinerea*) as a white grub parasite.

1875.

PECK, C. H.—Report of the Botanist. (Twenty-eighth Ann. Rep. N. Y. State Mus. Nat. Hist., for 1874, p. 70.)

Description of *Torrubia superficialis*, n. sp., from dead larvæ.

RILEY, C. V.—*Torrubia elongata*, the White Grub Fungus. (Colman's Rural World, June 12, 1875, v. –, p. —.)

Name of *Torrubia elongata* proposed for white grub fungus. Figures from specimens obtained in Missouri.

1876.

MANN, B. P.—Notes on the White Mountain Faunæ. (Psyche, July, 1876, v. 1, p. 183.)

Syrphus found infested by fungi (Entomophthoræ?).

1877.

COOKE, M. C.—The Hyphomycetous Fungi of the United States. (Bull. Buffalo Soc. Nat. Sci., 1877, v. 3: Feb., p. 189; July, p. 193.)

Five species of entomochthonous Isaria mentioned on p. 189.

RILEY, C. V.—[Note on the Development of *Torrubia elongata.*] (N. Y. Weekly Tribune, Oct. 4, 1877, v. —, p. —.)

1878.

——————[Occurrence of *Torrubia elongata* in South and West.] (N. Y. Weekly Sun, Sept. 12, 1878, v. —, p. —.)

SAUNDERS, W.—The Annual Address of the President of the Entomological Society of Ontario. (Can. Ent., Oct., 1878, v. 10, p. 183; Ann. Rep. Ent. Soc. Ont. for 1878, p. 5.)

Report of destructive disease (muscardine?) among nearly full-grown larvæ of *Clisiocampa sylvatica.*

1879.

COMSTOCK, J. H.—Report upon Cotton Insects, p. 217.

Report of unsuccessful experiments with yeast applications to cotton-worms (Aletia), made to test Hagen's proposed method of instituting fungous disease.

COMSTOCK, J. H.—[Entomological Note.] (Ann. Rep. Ent. Soc. Ont. for 1879, p. 22.)

Unsuccessful experiments with yeast as an insecticide.

GERARD, W. R.—The *Saprolegnia ferax.* (Proc. Poughkeepsie Soc. Nat. Sci., Dec., 1878, v. 4, p. 25.)

Life history of *Empusa muscæ*, on supposition of its connection with *Saprolegnia ferax* as a terrestrial state.

HAGEN, H. A.—Obnoxious Pests: Suggestions relative to their Destruction. (Can. Ent., Jan., 1879, v, 11, p. 110; Ann. Rep. Ent. Soc. Ont. for 1879, p. 22; Extract, Fourth Rep. U. S. Ent. Commiss., p. 188.)

Summary of studies by Dr. Theodor Bail tending to show that Mucor, Saprolegnia, Saccharomyces, and Empusa are different forms of the same fungus species, and that insects may become infected with fungi if fed with beer mash. Use proposed against injurious insects generally.

HAGEN, H. A.—Les insectes nuisibles. (Nat. Can., 1879, v. 11, p. 150.)

French translation of article in the "Canadian Entomologist" of this year, on yeast as an insecticide.

HAGEN, H. A.—Destruction of Obnoxious Insects, Phylloxera, Potato Beetle, Cotton-worm, Colorado Grasshopper, and Greenhouse Pests by Application of the Yeast Fungus.

Revised edition of the article on this subject in the "Canadian Entomologist," with additions relating to experiments—one of them apparently partially successful.

PECK, C. H.—Report of the Botanist. (Thirty-first Ann. Rep. N. Y. State Mus. Nat. Hist. for 1877, p. 20.)

Larvæ infesting alders in Adirondack region dead. Great numbers on the ground covered with white mold regarded by Peck as parasitic, and as cause of death.

PECK, C. H.—Report of the Botanist. (Thirty-first Ann. Rep. N. Y. State Mus. Nat. Hist. for 1877, pp. 19, 44; Hedwigia, Oct., 1881; Extract, 2d Ann. Rep. State Ent. N. Y., p. 178.)

Seventeen-year locust (*Cicada septendecim*) reported as affected by a fungus in New York in 1879. Forms mass of pale yellowish or clay-colored spores in the abdomen, causing posterior part of abdomen to fall away. Described (p. 44) as *Massospora cicadina* n. gen. et. sp.

Prentiss, A. N.—Fungi as Insecticides. (Rep. [U. S.] Commiss. Agr., 1879, p. 260.)

See Comstock, 1879.

Saunders, W.—Annual Address of the President of the Entomological Society of Ontario. (Can. Ent., Oct., 1879, v. 11, p. 186; Ann. Rep. Ent. Soc. Ont. for 1877, p. 7.)

Further report of a disease among nearly grown larvæ of *Clisiocampa sylvatica* in Canada.

Siewers, C. G.—Mold as an Insect Destroyer. (Am. Nat., Nov., 1879, v. 13, p. 681.)

Hagen's theory reiterated. Various instances reported of occurrence of fungous disease among larvæ.

Thomas, Cyrus.—The Chinch-bug, its History, Character, and Habits. (Bull. No. 5, U. S. Ent. Comm., 1879.)

Referring (p. 24) to Shimer's supposed epidemic among chinch-bugs, inclines to believe that moisture gave rise to a minute fungus as the direct cause of the death of the insects. Speaks of similar disease among house-flies and grasshoppers.

1880.

Comstock, J. H.—Fungi as Insecticides. (Rep. [U. S.] Commiss. Agr., 1879, p. 260.)

Abstract of unsuccessful experiments with yeast fungus by A. N. Prentiss, in the application of yeast fungus to plant-lice, scale insects, and red spiders.

Aitken, J.—Notes on a New Species of Caterpillar Fungus. (Hardwicke's Science Gossip, 1880, p. 97.) [Not seen.]

On Torrubia sp.

Hagen, H. A.—Schädliche Insecten durch den Hefenpilz zu tödten, (Zool. Anz., April 19, 1880. v. 3, p. 185.)

Report of successful experiment with yeast fungus for destruction of *Doryphora 10-lineata*, all treated dying in eight to twelve days and a check lot living through the winter. Hagen regards experimental recommendation as independent of theoretical explanation derived from Bail.

Hagen, H. A.—On the Destruction of Obnoxious Insects by Yeast. (Can. Ent., May, 1880, v. 12, p. 81.)

Experiments of Mr. J. H. Burns with yeast plant on Doryphora. Fifty treated beetles all died by the twelfth day, while only three of the check lot of fifty had died in six weeks, and only twenty-five died during the following winter and spring. Writer mentions also a seemingly successful experiment on aphides. Summarizes some recent European contributions to life histories of Entomophthoræ. Declares experimental results independent of Bail's theory, and reports finding fungus spores in sinus of wings of dead beetles which had been sprinkled with yeast. Successful use of yeast on aphides reported by letter from Germany.

HAGEN, H. A.—*Cordyceps ravenelii* on the larvæ of Phyllophaga. (Can. Ent., May, 1880, v. 12, p. 89.)

Cordyceps ravenelii received from Alabama. Curtis's description quoted.

HAGEN, H. A.—Ueber die Vernichtung Schädlicher Insecten durch den Hefenpilz. (Ent. Zeit. zu Stettin, July–Sept., 1880, v. 41, p. 355.)

Notice. (Berliner Ent. Zeit., 1881, v. 25, p. 295.)

LECONTE, J. L.—Fungoid Diseases of Insects: a Reclamation. (Can. Ent., July, 1880, v. 12, p. 126.)

Comparison of author's own first mention of fungus parasites as insecticides (see LeConte, 1873) with that of Walsh (see 1867).

PACKARD, A. S., Jr.—[Yeast Fungus as an Insecticide.] (Am. Nat., Feb., 1880, v. 14, p. 133.)

Mere mention.

PECK, C. H.—Fungi as Insect Destroyers. (Am. Nat., May, 1880, v. 14, p. 363.)

Reprint from Bulletin of Torrey Botanical Club concerning Peck's observations on cicada fungus.

PRENTISS, A. N.—Destruction of Obnoxious Insects by means of Fungoid Growths. (Am. Nat., 1880, v. 14, Aug., p. 575; September, p. 630.)

Full account of experiments with yeast on aphides, coccids, and red spiders.

RILEY, C. V.—Fungus Diseases of Insects. (Am. Ent., April, 1880, v. 3, p. 103.)

Abstract of article by Metschnikoff in *Zoologischer Anzeiger*, 1880, p. 44, relating to insect diseases in Europe, and experiments with muscardine fungi.

RILEY, C. V.—The White Grub Fungus. (Am. Ent., June, 1880, v. 3, p. 137.)

General article; illustrated summary of literature, and list of entomogenous species of Cordyceps. Quotes Berkeley's description of *Cordyceps ravenelii* and gives American bibliography of the genus.

RILEY, C. V.—Yeast Ferment: Fungus Infection. (Bull. No. 3, U. S. Ent. Comm., p. 68; Fourth Rep. U. S. Ent. Commiss. p. 188—see also Appendix III., p. [31].)

Report of experiments with yeast made according to Dr. Hagen's suggestion. Riley quotes at length from Hagen; describes unsuccessful experiments on larvæ of Papilio, Danais, and Pieris; gives a full account of a trial with cotton-worms (Aletia) by Prof. J. E. Willet; and mentions incidentally the occurrence of destructive disease among cabbage-worms (*Pieris rapæ*).

RILEY, C. V.—The Use of Fungus Growths to destroy Insects. (Am. Ent., Nov., 1880, v. 3, p. 269.)

Abstract of article by A. N. Prentiss in "American Naturalist" of this year.

SCHWARZ, E. A.—Disease of Chauliognathus larvæ. (Am. Ent., Nov., 1880, v. 3, p. 277.)

Note on disease causing larvæ to die without subsequent efflorescense of spores.

SEAMAN, W. H.—Some Remarks on Fungi considered as Insecticides. (Am. Ent., Feb., 1880, v. 3, p. 40.)

Statement and criticism of Hagen's view of relations of yeast fungi to insect diseases.

WILLET, J. E., and COOK, A. J.—Experiments with Yeast Ferment on Various Insects. (Am. Ent., Dec., 1880, v. 3, p. 289.)

Experiment on cotton worms (*Aletia*) with beer and yeast. Larvæ treated with beer all lived to the imago; while of those treated with yeast five died either as larvæ or pupæ. Experiment not regarded as successful. Entirely unsuccessful experiments by Cook with yeast on squash bugs (*Anasa*), potato beetles (*Doryphora*), cabbage-worms (*Pieris rapæ*), and plant-lice (*Erisoma tessellata*).

1881.

BESSEY, C. E.—Insect-destroying Fungi. (Am. Nat., Jan., 1881, v. 15, p. 52.)

Abstract of article by Giard on life history of Empusa. Mention of description of Cicada fungus by C. H. Peck.

LEIDY, JOSEPH.—Parasites of the Termites. (Journ. Acad. Nat. Sci. Phil., 1881, ser. 2, v. 8, p. 425.)

Excessive normal parasitism of Protozoa in termites.

OSBORN, HERBERT.—Occurrence of a bacterial disease in the bronze-colored cutworm (*Nephelodes violans*, Gueneé). (Iowa Homestead, June 17, 1881, v.—, p.—; First Ann. Rep. State Ent. N. Y., 1882, p. 105.)

VORCE, C. M.—Wholesale Destruction of Acari by a Fungus. (Proc. Am. Soc. Microscopists, 1881, v. 4, p. 49; Am. Monthly Micr. Journ., Sept., 1881, v. 2, p. 166.)

Dead mites observed with fungus spores.

1882.

FORBES, S. A.—The Chinch-bug in 1882. Field Notes. (Ill. Crop Prospects, Circular No. 92, Aug., 1882, p. 77.)

Reports that the chinch-bug is extremely subject to a minute internal parasite, a bacterial species, the spread and multiplication of which may account for those sudden disappearances of vast numbers of the bugs which have hitherto been attributed to the weather.

FORBES, S. A.—Bacterium a Parasite of the Chinch-bug. (Am. Nat., Oct., 1882, v. 16, p. 824.)

Observation of bacteria in alimentary canal of chinch-bugs apparently affected by disease.

FORBES, S. A.—Another Chinch-bug Parasite. (Prairie Farmer, Dec. 9, 1882, v. —, p. —.)

Suggests that white mold of chinch-bugs mentioned in Popenoe's article (see below) is identical with Entomophthora found by Forbes destroying chinch-bugs in corn near Jacksonville, Ill., September, 1882. Reports successful cultivation of *Micrococcus insectorum* in beef broth. Thinks there is a "working possibility" of using germs of contagious disease for destruction of insects. Considers it quite unlikely that chinch-bugs will appear in destructive numbers next year.

HAGEN, H. A.—Experiments with Yeast in destroying Insects. (Can. Ent., Feb., 1882, v. 14, p. 38; Rep. Ent. Soc. Ont., 1882, p. 29.)

Publishes, with comments, letter from horticulturist giving result of experiments with yeast fungus—one apparently successful; others without effect. Reports similar variable results from Germany.

HAGEN, H. A.—[On the Destruction of Insect Pests by the Application of Yeast.] (Am. Monthly Micr. Journ., Sept., 1882, v. 3, p. 179.)

Brief mention of Hagen's views.

POPENOE, E. A.—The Chinch-bug and the Season. (Quart. Rep. Kan. State Board Agr., Sept., 1882; Reprinted in Prairie Farmer, Nov. 25, 1882, v. —, p. —.)

Quotes recent statements of many Iowa farmers that chinch-bugs died in large numbers upon corn stalks, each being covered with a strong growth of white mold. Suggests connection between this observation and that of Shimer in 1867.

1883.

BESSEY, C. E.—A New Species of Insect-destroying Fungi. (Am. Nat., Dec., 1883, v. 17, pp. 1280, 1286; Bull. Iowa Agr. Coll., Dept. Ent., 1884, No. 2, p. 84.)

Description of *Entomophthora calopteni*, n. sp.

Bessey, C. E.—[*Entomophthora calopteni* parasitic on *Caloptenus differentialis.*] (Scientific and Literary Gossip, Dec. 15, 1883, v. 2, p. 40.)

Burrill, T. J.—New Species of Micrococcus (Bacteria.) (Am. Nat., March, 1883, v. 17, p. 319.)

Original description of *Micrococcus insectorum* from chinch-bug (*Blissus leucopterus*).

Cook, A. J.—The Bee-keepers' Guide, or Manual of the Apiary. 9th ed., pp. 309, 310.

Remarks on foul-brood of bees.

Farlow, W. G.—[Description of *Botrytis rileyi*, Farlow.] (Rep. [U. S.] Commiss. Agr., 1883, p. 121.)

Describes a new species of muscardine fungus found on the larvæ of Plusia.

Forbes, S. A.—Studies on the Chinch-bug. I. (Twelfth Rep. State Ent. Ill., 1882, p. 47.)

Elaborate article on contagious diseases of chinch-bug, occupying eleven pages. Quotes previous publications of LeConte, Shimer, and Thomas; describes discovery of *Micrococcus insectorum* of chinch-bug, describing and figuring the species; reports observation of chinch-bugs dead with Entomophthora; prints translation of article by Metschnikoff on diseases of *Anisoplia austriaca* and *Cleonus punctiventris*, published in *Zoologischer Anzeiger* for 1880; and suggests that effect of wet weather is produced by stimulating development of fungus parasites.

Forbes, S. A.—Memoranda with regard to the Contagious Diseases of Caterpillars and the Possibility of using the Virus of the same for Economic Purposes. (Can. Ent., Sept., 1883, v. 15, p. 171; Am. Nat., Nov., 1883, v. 17, p. 1169.)

Abstract of article read at Minneapolis meeting of the A. A. A. S.

Forbes, S. A.—Experiments with Diseased Caterpillars. (Science, Oct. 5, 1883, v. 2, p. 483.)

Preliminary note on bacterial disease of native caterpillars.

Forbes, S. A.—A New Insect Disease. (Prairie Farmer, Oct. 6, 1883, v. —, p. —.)

Flacherie of *Pieris rapæ.*

Forbes, S. A.—[Notes on the Diseases of Caterpillars.] (Farmers' Review, Dec. 27, 1883, v. 11, p. 419.)

Brief report of address to Illinois State Horticultural Society. (See Forbes, 1884.)

Forbes, S. A.—Entomological Notes of the Season. (Ill. Crop Rep., No. 106, Dec., 1883, p. 178.)

Season especially characterized by occurrence of contagious diseases among insects, due to bacteria and other fungus parasites,

which may be artificially cultivated, and which when sown or sprinkled upon food of healthy insects produce diseases as a consequence.

DE LA COUR, J. L.—Sporendonema; or the Fungus which is now so Prevalent among House-flies. (Am. Monthly Micr. Journ., Jan., 1883, v. 4, p. 19.)

Rehearsal of general facts concerning *Empusa muscæ.*

OSBORN, HERBERT.—An Epidemic Disease of *Caloptenus differentialis.* (Am. Nat., Dec., 1883, v. 17, p. 1286; Bull. Iowa Agr. Coll., Dept. Ent., Aug., 1884, No. 2, p. 83.)

Account of entomophthorous disease generally prevalent in central Iowa, affecting *Caloptenus differentialis.*

RILEY, C. V.—[Remarks on an Epidemic Disease of *Caloptenus differentialis.*] (Am. Nat., Dec., 1883, v. 17, p. 1287; Bull. Iowa Agr. Coll., Dept. Ent., Aug., 1884, No. 2, p. 85.)

Riley surmises that insects died from insect parasitism, and that Entomophthora is a later development.

RILEY, C. V.—The Cabbage Plusia. (Rep. [U. S.] Commiss. Agr., 1883, p. 121.)

Fungous disease reported. Parasite described by Farlow as *Botrytis rileyi.*

RILEY, C. V.—Reports of Experiments, chiefly with Kerosene, upon Insects injuriously affecting the Orange-tree and the Cotton Plant, made under the Direction of the Entomologist. (U. S. Dept. Agr., Div. Ent., Bull. No. 1, p. 25.)

Notice of a fungoid growth on Parlatoria and Mytilaspis, in a report made by Joseph Voyle.

1884.

BURRILL, T. J.—Experiments in Silk Culture. (Twelfth Report Board of Trustees Illinois Industrial University, p. 85.)

Account of contagious disease of silkworm which destroyed all but a few hundred of about 80,000 worms hatched for an experiment in silk culture. General discussion of *flacherie* of silkworm.

FLETCHER, JAMES.—[Muscardine in *Agrotis fennica.*] (Can. Ent. Nov., 1884, v. 16, p. 214; Fifteenth Ann. Rep. Ent. Soc. Ont., p. 21.)

Destruction of great numbers of larvæ of *Agrotis fennica* by an Entomophthora.

FORBES, S. A.—On a Contagious Disease of Caterpillars. (Trans. Ill. Hort. Soc., 1883, v. 17, p. 29)

General article giving account of results of original observations and experiments. Describes experiments of Pasteur with *flacherie* of silkworm. Gives an account of his own observations and experiments with the prevalent disease of the European cabbage worm and the *flacherie* of the apple and walnut caterpillars (Datanas).

FORBES, S. A.—Notes of the Year. (Thirteenth Rep. State Ent. Ill., p. 10.

Mentions occurrence of contagious disease among forest tent-caterpillars (*Clisiocampa sylvatica*) in extreme Southern Illinois, and continued prevalence of disease of European cabbage worm.

LEIDY, JOSEPH.—Ant infested with a Fungus. (Proc. Acad. Sci. Phil., Jan. 1, 1884, p. 9.)

Note on an undescribed fungus attacking *Camponotus pennsylvanicus.*

NEW YORK MICROSCOPICAL CLUB.—[Proceedings] June 6. (Science, July 4, 1884, v. 4, page 25.)

Account, by J. L Zabriskie, of a coniomycetous fungus on Dro sophila, a few specimens having been found in the State of New York; and description, by C. H. Peck, of this fungus as a new genus and species (*Appendicularia entomophila*) allied to Cordyceps.

WRIGHT, R. RAMSAY.—[On the Corpuscles of *Pébrine.*] Scientific and Literary Gossip, Jan. 15, 1884, v. 2, p. 70.)

1885.

FLETCHER, JAMES.—[Remarks upon Cutworms.] (Fifteenth Ann. Rep. Ent. Soc. Ont., p. 21.)

Account of an enormous "fatality" among cutworms (larvæ of Agrotis) caused by an entomophthorous fungus.

FYLES, T. W.—[Fungous Disease of Cutworms.] (Fifteenth Ann. Rep. Ent. Soc. Ont., p. 22.)

Mention of occurrence of insect disease in England.

RILEY, C. V.—The Periodical Cicada. (Bull. U. S. Dept. Agr., Div. Ent., No. 8, p. 12.)

Refers to fungus on *Cicada septendecim* mentioned by Dr. Leidy in 1851. and described by Peck as *Massospora cicadina.* Quotes from Pennsylvania correspondent description of fungus in abdomen, posterior part of body being filled by a greenish fungus. Male specimen received by Riley in 1868 had interior part of abdomen converted into what appeared to be a brown mold. Further description of this fungus quoted from R. H. Warder, of Ohio.

RILEY, C. V.—Silk Culture. (Rep. [U. S.] Comm. Agr. 1885, p. 214.)

Mentions the common silkworm diseases, *grasserie*, *muscardine*, *flacherie*, and *pébrine*, and describes at length the symptoms, nature, and treatment of the last two.

SAUNDERS, W.—On some of Nature's Methods of subduing Injurious Insects. (Trans. Am. Hort. Soc., 1885, v. 3, p. 178.)

Mention of fungous disease of *Clisiocampa sylvatica* and *Agrotis fennica*.

SAUNDERS, W.—Annual Address of the President of the Entomological Society of Ontario. (Can. Ent., Dec., 1885, v. 17, p. 237.)

Remarks on the general subject of insect diseases, with notes of recent work done.

WOODWORTH, C. W.—Silkworm Notes. Silkworm Diseases. (Ill. Crop Prospects, Crop Rep. No. 125, p. 25.)

Description of jaundice of silkworm as occurring in experiment at University of Illinois.

ZABRISKIE, J. L.—A Caterpillar Fungus from New Zealand, and some related Species of the United States. (Journ. N. Y. Micr. Soc., April, 1885, v. 1, p. 89.)

Cordyceps on caterpillars, white grubs, and a Lecanium.

1886.

ARTHUR, J. C.—A New Larval Entomophthora. (Botan. Gaz., Jan., 1886, v. 11, p. 14.)

Describes and figures *Entomophthora phytonomi* on *Phytonomus punctatus*.

ARTHUR, J. C.—Disease of Clover-leaf Weevil, *Entomophthora phytonomi*, Arthur. (Fourth Ann. Rep. N. Y. Agr. Exper. Station, for 1885, p. 258.)

Illustrated account of an epidemic disease, with description and figures of the Entomophthora concerned. No resting spores found.

FORBES, S. A.—The Chinch-bug in Illinois. (Prairie Farmer, September 25, and Oct. 2, 1886, v. —, p. —.)

Two forms of epidemic or contagious disease now known to attack the chinch-bug with immense effect, one observed, though not critically studied, by Dr. Shimer, in 1865, and the other discovered by Forbes, in 1882, the former apparently largely dependent upon wet weather, the latter seemingly not.

BUTLER, A. W.—The Periodical Cicada in Southern Indiana. (U. S. Dept. Agr., Div. Ent., Bull. 12, p. 24.)

Mentions a fungous disease of the cicada (probably due to *Massopora cicadina*), giving the result of Dr. E. G. Grahn's microscopical examination of diseased specimens. This gentleman criticises Dr. Riley for quoting without comment (Bull. 8, Div.

Ent.) a correspondent's statement that the disease seemed to be confined to imperfect males and due to decomposition, since in his own investigations he has found it otherwise. Spherical organized bodies present which he describes, regarding them as sporangia filled with spores and multiplying by fission. Mr. Butler says: "I am satisfied that the greater number of cicadas which escape a forcible death die from the effects of the fungus previously mentioned." [*Massopora cicadina.*]

FORBES, S. A.—A Contagious Disease of the European Cabbage Worm, *Pieris rapæ,* and its Economic Application. (Proc. Seventh Ann. Meeting Soc. Promotion Agr. Sci., 1886, p. 26; Thirteenth Rep. Bd. Trustees Univ. Ill., p. 294.)

General argument favorable to economic use of contagious insect diseases. Classifies them as hyphomycosis, schizomycosis, and sporozosis. Elaborate description of *flacherie* of European cabbage worm, and history of its appearance and spread in the United States. Gives accounts of two attempts to convey it by transfer of diseased larvæ to new localities. Describes successful cultures and infection experiments with *Pyrameis cardui.*

FORBES, S. A.—[*Flacherie* in *Pieris rapæ.*] (Miscellaneous Essays on Economic Entomology by the State Entomologist [Illinois] and his Assistants, p. 5)

Elaborate description of the symptoms and the anatomical and histological character of the disease.

FORBES, S. A.—Studies on the Contagious Diseases of Insects. (Bull. Ill. State Lab. Nat. Hist., v. 2, p. 257.)

An elaborate article giving results of observations and author's experimental studies on bacterial disease of *Pieris rapæ*, Datana larvæ, *Mamestra picta,* and silkworm, with brief account of epidemic of muscardine in *Clisiocampa sylvatica.* Illustrated by photographs of Micrococcus of cabbage worm.

RILEY, C. V.—Silk Culture. (Rep. [U. S.] Commiss. Agr., 1885, p. 221.)

A discussion of *flacherie* and *pébrine* of the silkworm, giving a description of the symptoms, consequences, nature, and treatment of *flacherie,* and a translation of Pasteur's instructions for detecting flaccidity in the chrysalis; and describing the symptoms of *pébrine* and the tests for its determination, giving Maillot's method of isolating and examining the moths, further details of procedure necessary to securing purity of stock, and a brief characterization of the corpuscles of *pébrine.*

RILEY, C. V.—The Mulberry Silkworm: A Manual of Instructions in Silk-culture. (U. S. Dept. Agr., Div. Ent., Bull. 9.)

In Chapter V. of this Bulletin (see p. 33) the four principal diseases of the silkworm (*muscardine, pébrine, flacherie,* and *grasserie*) are considered, *gattine* being mentioned as a variety of *pébrine* (Pasteur's view) or *flacherie* (Maillot). Short account of the prevalence of these diseases in France and of investigation by M. Guérin Méneville in 1849 and by Pasteur later. The diseases are each characterized, their external and internal symptoms are described, and various theories concerning the cause of *muscardine* and *pébrine* are mentioned. No remedies known for *muscardine*, but certain measures recommended as checks to the disease and to its spread. As spores "retain their power of communicating disease for at least three years," cleaning and fumigating are very necessary.

Pébrine is entirely dependent upon the presence and multiplication of corpuscles (Microsporidiæ) in the bodies of diseased worms. The disease is said to be both contagious and infectious, external symptoms usually appearing in four or five days after the corpuscles enter the intestines. The effect on the progeny depends upon the age of the worm when infected, and a system of selecting eggs is founded on this fact. (The details of Pasteur's system of microscopical selection of eggs for both *pébrine* and *flacherie*—the only diseases which necessitate care in this particular—are given in chapter VI. of this Bulletin.)

Flacherie is caused, according to Pasteur, by the development and multiplication of micro-organisms. The Italians claim that these are not always present in the flaccid worm, and are therefore a result of the disease rather than the primitive cause. Disease highly infectious, and no satisfactory remedy known, preventive measures affording the only safety.

Grasserie said to be of little importance, since it is neither contagious nor hereditary. Maillot's description given. *Pébrine* the only disease of the four which is hereditary in the true sense, *flacherie* and *muscardine* being only indirectly so.

1887.

Forbes, S. A.—The Present Condition and Prospects of the Chinch-bug in Illinois. (Bull. Office State Ent. Ill. No. 2, 1887, p. 42; Fifteenth Rep. State Ent. Ill., p. 102.)

Refers to artificial cultivation of the germs of the contagious diseases of the chinch-bug as a theoretical remedy only, requiring much additional study and experiment to make it practically useful.

Osborn, Herbert—The Economic Utility of the Diseases of Insects. (Trans. Iowa State Hort. Soc., 1886, v. 21, p. 400.)

Summary of facts intended to show what practical use may be made of insect diseases, presenting brief descriptions of contagious diseases of silkworms, bees, flies, grasshoppers, and white grubs. As illustration of practical use, reports introduction into Iowa, from Illinois, of *flacherie* of European cabbage worm in 1883. Mentions disadvantages of period of incubation. Considers bacterial diseases most likely to prove useful, but believes that "spread in nature will be affected by conditions beyond our control."

1888.

FORBES, S. A.—On the Present State of our Knowledge concerning Contagious Insect Diseases. (Address as retiring President of the Cambridge Entomological Club, Jan. 14, 1887.) (Pysche v. 5, p. 3.)

General summary of knowledge on the subject, with special reference to biological problems and utilization.

FORBES, S. A.—Contribution to American Bibliography of Insect Diseases. (Pysche, v. 5, pp. 15, 45.)

Bibliographical list.

FORBES, S. A.—Note on Chinch-bug Disease. (Psyche, v. 5, p. 110.)

Distinguishes three diseases of *Blissus leucopterus*: one due to a Botrytis (Sporotrichum); one to an Entomophthora; and the third to a microbe (*Micrococcus insectorum,* Burrill). Botrytis much more abundant and destructive in Illinois than the Entomophthora. Believes that these diseases will soon suppress existing chinch-bug outbreak.

FORBES, S. A.—[Chinch-bug Diseases.] (Farmers' Review, Oct. 31, 1888, v. 19, p. 692.)

Reports three contagious diseases among chinch-bugs, one of them new, resembling muscardine of the silkworm and produced by a Botrytis. Uncertain as to economic usefulness of these diseases, but surmises that disappearance of chinch-bugs in Northern Illinois in 1864 was due to one of them. Vast numbers of chinch-bugs killed by them this fall (1888) in Southern Illinois. Have been reported by other observers in Minnesota, Iowa, and Ohio.

FORBES, S. A.—[Epidemic Diseases of the Chinch-bug in Illinois.] (Insect Life, v. 1, No. 4, Oct., 1888, p. 113.)

Mention of the widespread and destructive character of two chinch-bug diseases in Illinois, one bacterial and the other due to an Entomophthora. Ground in some fields so thickly sprinkled with bugs dead with latter disease as to suggest a flurry of snow; and the bacterial affection seems to be even more destructive, although less conspicuously so.

GILLETTE, C. P.—[A New Chinch-bug Enemy.] (Prairie Farmer, Aug. 11, 1888, v. 60, p. 518.)

Fungous disease (Entomophthora) destroying millions of chinch-bugs on the grounds of the Iowa Agricultural Experiment Station.

GILLETTE, C. P.—Chinch-bug Diseases. (Bull. 3, Agr. Exper. Station, Iowa, Nov., 1888, p. 57.)

Refers to Shimer's and Lugger's observations. Reports unusual prevalence of fungous diseases of plants and animals this year in Iowa, including fungous diseases of the chinch-bug. Describes appearance of chinch-bug disease (Entomophthora) and gives illustrative figure, with history of its development. Gives life history of Entomophthora with illustrations by the Station Botanist. Suggests that crops subject to chinch-bug attack be grown on low ground when possible, and advises preservation of bugs dead with disease for future use.

Howard, L. O.—The Chinch-bug; a general Summary of its History, Habits, Enemies, and of the Remedies and Preventives to be used against it. (Bull. U. S. Dept. Agr. Div., Ent., No. 17; Rep. [U. S.] Commiss. Agr., 1887, p. 51.)

Quotes (p. 63) Shimer's article of 1867 (Proc. Acad. Nat. Sci. Phil.) and Forbes's summary from his First Report as State Entomologist of Illinois (1882). Refers to Metschnikoff's article in the *Zoologischer Anzeiger* for 1880 (p. 44), and to other minor items.

Lugger, Otto.—Fungus which Kill Insects. (Bull. 4, Minn. Exper. Station, Oct., 1888, p. 26; Rep. Dept. Agr. and Agr. Exper. Station, Univ. Minn., 1887–88, p. 380.)

A general discussion, with illustrations, of diseased grasshoppers, silkworms, cabbage worms, house-flies and chinch-bugs. Describes occurrence of chinch-bug disease in spring of 1888, together with experiment for its dissemination in southern Minnesota.

Lugger, Otto.—Notes on the Chinch-bug in Minnesota. (Insect Life, v. 1, No. 4, Oct., 1888, p. 113.)

Note concerning the prevalence of a fungous disease (Entomophthora) of the chinch-bug in the southern counties of Minnesota in September, 1888, possibly due to the artificial introduction of diseased bugs which were mailed from the Agricultural Experiment Station to farmers there early in August. Apprehends little trouble in 1889. He says: "Chinch-bugs are nearly exterminated wherever the disease has been artificially introduced. But the disease has also been at work at quite a distance from these centers of introduction, and consequently I am in doubt whether I re-introduced the disease or not." At the Station the disease first appeared in holes used as traps for the bugs, spreading thence to fields of oats and wheat, and increasing rapidly until the weather became very hot and dry, when the disease was arrested except in very low or well-shaded fields.

1889.

Forbes, S. A.—The Entomological Record for 1885–86. (Fifteenth Rep. State Ent. Ill., p. 1.)

Reports prevalence and abundance of cabbage-worm *flacherie* in 1885.

Forbes, S. A.—Studies on the Chinch-bug. II. (Advance Sheets from Sixteenth Rep. State Ent. Ill., pp. 1, 45 and 56; same pp. of Report cited.)

"The recent widespread appearance of three destructive contagious diseases of the chinch-bug, and a consequent diminution of its numbers, makes it seem at last unlikely that any extraordinary loss will follow next year in the territory which has been so long infested."

Reviews the writer's earlier work on contagious diseases of the chinch-bug characterized by bacteria and Entomophthora, beginning in 1882. Reports finding dead chinch-bugs in Southern Illinois enveloped in Botrytis [Sporotrichum] July 7, 1887, and much more abundantly August 7, 1888; also occurrence of infections by Entomophthora and bacteria. Gives particulars of observations in field and laboratory, together with culture experiments. Cultures of *Bacillus insectorum* were repeatedly successful, but similar experiments with Entomophthora and Botrytis [Sporotrichum] failed. "At present it appears that all except perhaps the bacterial disease are closely dependent for their activity on the weather, although their generally rapid development over so large a territory indicates their presence at all times to a greater or less extent. * * * In order to obtain the free and rapid development of the Entomophthora or Botrytis [Sporotrichum] it was necessary to enclose the chinch-bugs under glass over moist earth. * * * That it is chiefly to the joint action of these various disease-producing fungi, favored as they are by moist weather, that we owe the disappearance of chinch-bug outbreaks, is rendered almost certain by the facts now on record."

Forbes, S. A.—Chinch-bug Probabilities. (Belleville, [Ill.] Advocate, March 15, 1889.)

Three contagious diseases prevalent last September and October in south-central and north-southern Illinois; one an intestinal disease, due to a bacillus; and the others, to spore-producing fungi. Each killed off vast numbers of chinch-bugs in the corn. Similar occurrences in 1864 and 1882 followed by long relief from chinch-bugs, and occurrence last fall adds a hopeful feature to the present situation, as wet weather would be almost certain to take more prompt and vigorous effect because of the presence of this contagious malady. Dry weather the coming season, on the other hand, may check them.

Riley, C. V.—The Chinch-bug Entomophthora. (Insect Life, v. 2, No. 5, Nov., 1889, p. 126.)

A critical notice of an article in the "Lawrence [Kansas] Daily Journal," concerning experiments by Prof. F. H. Snow.

Riley, C. V.—The Work of Field Agents. (Rep. Sec. of Agr. [U. S.] 1889, pp. 359, 360.)

Note of unsatisfactory field experiments made by Mr. F. M. Webster in Indiana with fungous diseases of the chinch-bug which prove that these diseases will not spread unless great masses of the fungus occur and the weather be "over-moist." Also mentions the spontaneous occurrence of a fungous disease of the differential locust (*Melanoplus differentialis*) caused by *Entomophthora calopteni.*

Snow, F. H.—The Chinch-bug, *Blissus leucopterus*, Say. (Sixth Biennial Rep. Kan. State Bd. Agr., 1887–88, p. 205.)

Discussion of germ-theory of disease and its applications, with note of Prof. Forbes's investigations of the contagious diseases of insects, especially of the chinch-bug. Thinks the sudden and complete disappearance of this insect in large parts of Kansas in May, 1888, was due to bacterial disease. Mentions attempt by Dr. Lugger to convey fungous disease of chinch-bug from fields in Kansas to fields in Minnesota by the transportation and distribution of diseased bugs. Disease spread rapidly, but may have occurred spontaneously. Believes that the artificial introduction of bacterial and fungoid diseases will be a valuable ally in the warfare against insects.

1890.

Bruner, Lawrence.—Report on Nebraska Insects. (Bull. 22, U. S. Dept. Agr., Div. Ent., p. 95.)

Mentions (p. 104) prevalence of a disease among grasshoppers (chiefly *Melanopus differentialis*) in summer of 1889 in and around Lincoln, Nebraska, which nearly exterminated these insects. Appends Prof. Bessey's description of the fungus causing it—*Entomophthora calopteni*, considered by Prof. Thaxter as identical with *Entomophthora grylli*.

Cook, A. J.—Foul Brood. (Bull. Mich. Agr. Exper. Station, No. 61.)

Popular account of fungoid diseases in general and of the species (*Bacillus alvei*) causing foul-brood; symptoms of the disease described, and preventive and remedial measures considered. A "nameless bee disease," probably due to *Bacillus gaytoni*, is also characterized and a remedy given.

Cushman, S.—Foul Brood. (Bull. R. I. Agr. Exper. Station, No. 9, p. 111.)

Not seen. The following abstract is taken from the "Experiment Station Record" (U. S. Department of Agriculture), Vol. 2, No. 11, June, 1891, p. 662: "An account of the bacterium (*Bacillus alvei*) causing foul-brood, the symptoms of the disease, the remedies which may be employed to destroy the germs, and the methods of repressive and preventive treatment. Particular reference is made to successful experiments by Messrs. Sproule and Webster with formic acid."

Forbes, S. A.—General Record for 1887 and 1888. (Sixteenth Rep. State Ent. Ill., p. IX.)

Reports continued prevalence of *flacherie* of European cabbage worm during the years 1887 and 1888.

Osborn, Herbert.—On the Uses of Contagious Diseases in Contending with Injurious Insects. A Paper read before the Entomological Club of the A. A. A. S. at Indianapolis, Aug. 22, 1890. (Insect Life, v. 3, No. 4, Nov., 1890, p. 141.)

Summing up the considerations brought forward in the paper the author says, "I think we are justified in the following inferences:

"*First.* That there are diseases amply sufficient as a basis for economic work, the bacterial forms giving the most promise for all cases where early results are desired, while those due to fungi, so far as present knowledge goes, propagating slowly, can only be used as slow but efficient checks to injurious forms, the most we can do with them being to introduce them in localities where not already found.

"*Second.* That the diseases can be controlled to the extent of preserving the germs for a season and transporting them from place to place to use for inoculation, but that their spread in nature will be affected by conditions beyond our control, while only such insects as occur gregariously or live in mingled hosts can be attacked to advantage.

"*Third.* That the cost of application would prevent its adoption except in certain forms.

"Finally, we must consider this method of contending with insects at best as but one of a number of profitable methods to be used in certain cases where other methods are insufficient and to supplement other methods where it can be done to advantage. With this end in view, the diseases of insects are worthy of the most careful study, and will not, I think, disappoint us in their final results."

Snow, F. H.—Experiments for the Artificial Dissemination of a Contagious Disease among Chinch-bugs. (Trans. Kan. Acad. Sci., 1889–90, v. 12, pt. 1, p. 34.)

"White fungus disease" (produced by "Entomophthora or Empusa") successfully propagated in laboratory by imprisoning healthy chinch-bugs with sick and dead ones, and infected specimens sent to eight states. Results exceedingly satisfactory as indicated by correspondence with farmers.

Snow, F. H.—Experiments in 1890 for the Artificial Dissemination of Contagious Diseases among Chinch-bugs. (Trans. Kan. Acad. Sci., 1889, v. 12, 1889–90, pt. 1, p. 119.)

Account of laboratory field experiments with three diseases, Entomophthora or Empusa, Micrococcus, and Isaria or Trichoderma appearing in the infection jars before the close of the season. Of the twenty-six reports from the field nineteen decidedly favorable.

Snow, F. H.—Experiments for the Artificial Dissemination of Contagious Diseases among Chinch-bugs. (Proc. Nineteenth Ann. Meeting Kan. State Bd. Agr., 1890, pp. 142–144.)

Not seen.

Snow, F. H.—Experiments for the Destruction of Chinch-bugs. (Twenty-second Ann. Rep. Ent. Soc., Toronto, 1890, p. 193.)

Not seen.

Webster, F. M.—Report of Observations upon Insects affecting Grains. (Bull. U. S. Dept. Agr., Div. Ent., No. 22, p. 42.)

An account (p. 60) of precise experiments in laboratory and field with a fungous disease of the chinch-bug supposed to be due to Entomophthora, especially valuable as determining the effect of moisture upon the propagation of this disease. "The only way that this fungoid disease seems capable of being employed in agriculture is by the establishment of some central propagating station to which farmers can apply and receive an abundant supply of infected bugs on short notice. By this means they could take advantage of a rainy period of a week or ten days, and, if they can contrive by sowing plats of millet and Hungarian to mass the bugs in certain localities about their fields, they might accomplish something towards warding off an invasion. But the possibility of overcoming an invasion after it is fully under way, as is almost sure to be the case during a dry season, it must be confessed is not very encouraging."

1891.

Comstock, J. H., and Slingerland, M. V.—Wireworms. Results of Efforts to discover a Practicable Method of preventing the Ravages of these Pests, and a Study of the Life History of several Common Species. (Bull. Cornell Univ. Agr. Exper. Station, No. 33, p. 211.)

Mention of frequent occurrence of "fungus-killed larvæ" in cages of wireworms. Death probably due to *Metarrhizium anisopliæ.*

Cook, A. J.—[On Carrying Chinch-bug Disease over Winter.] (Insect Life, v. 3, No. 6, March, 1891, p. 285.)

Thinks it might be done, since foul-brood is carried over winter in beehives.

Fletcher, James—[Chinch-bug Disease.] (Insect Life, v. 3, No. 6, March, 1891, p. 285.)

"Where the disease has been it is likely to appear again when proper conditions are present."

Snow, F. H.—First Monthly Report to Official State Paper, as required by law. (Topeka Daily Capital, April 14, 1891.)

Not seen.

Forbes, S. A.—General Record for 1889 and 1890. (Seventeenth Rep. State Ent. Ill., p. ix.)

Reports verification of prediction in previous Report (see 16th Rep. State Ent. Ill., p. 2). Vast destruction of chinch-bugs by disease in the late autumn of 1889. Brief period of alarm here and there in spring of 1889, but by the end of summer chinch-bugs had practically all disappeared, crops of infested region being the best known there for many years. Speaks of possible economic use of the spontaneous diseases of chinch-bugs.

FORBES, S. A.—On a Bacterial Disease of the Larger Corn-Root Worm (*Diabrotica 12-punctata*, Oliv.). (Seventeenth Rep. State Ent. Ill., pp. xi and 71.)

Mentions bacterial disease which turns the larva red. Particulars of symptoms given, and of progressive attack and *post-mortem* appearances. Successful cultures reported, with description of characters of growth on liquid and solid media. Colors media first orange-red and then blood-red.

FORBES, S. A.—On the Common White Grubs (Lachnosterna and Cyclocephala). (Seventeenth Rep. State Ent. Ill., p. 45.)

Reports death of great numbers of white grubs in field and laboratory, apparently from bacterial disease.

FORBES, S. A.—Notes on the Diseases of the Chinch-bug. (Seventeenth Rep. State Ent. Ill., p. 74.)

Comprehensive article, containing summary of previous work on this subject by the writer, with reference to work of Lugger, Snow, and Webster. Doubtfully successful cultures of *Micrococcus* [*Bacillus*] *insectorum*, Burrill. Various culture and infection experiments with *Sporotrichum globuliferum*. Description of the fungus, with list of species infected with it. Analytical list and summary of articles on the subject published in 1882–91.

FORBES, S. A.—On a Bacterial Insect Disease. (N. Am. Practitioner, 1891, p. 401; Am. Monthly Micr. Journ., 1891, p. 246.)

Describes supposed disease of chinch-bug characterized by presence of bacteria in cœca of alimentary canal. This canal described at length, together with affection of cœcal cells in which *Micrococcus insectorum* is found. Apparent effects on the chinch-bug. Description of methods of isolation and of culture experiments.

GARMAN, H.—[Diseases of *Pieris rapæ* believed to be non-transferable to other species.] (Insect Life, v. 3, Nos. 7 and 8, April, 1891, p. 333.)

States that in a field at Lexington, Ky., where *Pieris rapæ* and *P. protodice* were about equally common, although seventy-five per cent. of *rapæ* were affected, not a case of a diseased *protodice* was noted. He says, "with the dead larvæ of *P. rapæ* abundant in the cabbage, and their fluids constantly spread over the leaves by dews and rains, a better test, on a larger scale, of the communicability of this disease could scarcely have been devised." Laboratory experiments with it to the same effect. Thinks that experiments for the destruction of the boll-worm should not be made with bacteria of disease of *P. rapæ*. Suggests as more promising, diseases which affect the forest tent caterpillar or the striped cutworm.

GILLETTE, C. P.—[Notes on Insect Disease.] (Insect Life, v. 3, No. 6, March, 1891, p. 259.)

Mentions destruction of several kinds of caterpillars by disease at Ames, Iowa.

MALLY, F. W.—The Boll Worm of Cotton. A Report of Progress in a Supplementary Investigation of this Insect. (U. S. Dept. Agr., Div. Ent., Bull. 24, p. 48)

Short synopsis of work on insect diseases in progress in Louisiana. Experiments indicate the susceptibility of the boll-worm to "cabbage-worm disease," though they are not positively conclusive. Boll-worm found subject to a spontaneous disease, and cultures from egg, larva, and pupa made. It is not yet known whether it is contagious. Reports the discovery of a disease each for two other insect larvæ (*Prodenia lineatella* and an undetermined noctuid), both prevalent and fatal, and barely mentions diseases of *Agrotis messoria* and *Nephelodes minians*, of which cultures were made.

POPENOE, E. A.—The Chinch-bug Disease again. (Manhattan Nationalist, Feb. 13, 1891.)

Corrects misapprehension and consequent misrepresentation of a reporter of the "Nationalist"; indicates briefly some points in the history of investigations with chinch-bug diseases; and, as contributing to general information on the subject, quotes from Dr. Lugger's bulletin article on "Fungi which Kill Insects." As an inference from his own and others' observations says that bugs will thrive even though the Empusa parasite is present unless weather conditions are favorable to its growth, in which latter case an epidemic of the disease is likely to occur whether the germs have been artificially introduced or not.

RILEY, C. V.—The Outlook for Applied Entomology. Annual Address as President of the Association of Economic Entomologists. (Insect Life, v. 3, No. 5, Jan., 1891, p. 181.)

Under the heading, "Contagious Germs in the Field," (p. 197) speaks doubtfully of the practicability of utilizing them for the rapid dissemination of disease in view of the delicate questions involved. Considers the difficulties greater with diseases of cryptogamic nature than with those of bacterial origin. Says, however, that "if the work of Snow and Lugger should be fully substantiated, the best results have so far been obtained with the Entomophthora of the chinch-bug. Success, if possible, will come only by investigation upon thoroughly careful and scientific lines, such as those begun and still pursued by Prof. Forbes." Mentions prospective investigations with disease germs for the boll-worm (*Heliothis armigera*), which has already been found susceptible to the cabbage-worm Micrococcus (*M. pieridis*), although he considers another and quite distinct Micrococcus—that which affects *Nephelodes violans*—as the most promising germ.

RILEY, C. V.—[A Discouraging Fact in Prof. Snow's Experiments.] (Insect Life, v. 3, No. 6, March, 1891, p. 279.)

Carrying healthy bugs through the season without infection, in the same room with diseased bugs, "would indicate either that the germs were easily kept from reaching the bugs or that they were not carried long distances. If close proximity to or actual contact with diseased individuals is requisite, the value of using germs of disease in the field is materially lessened. Farmers' evidence needs careful weighing.

RILEY, C. V.—Micro-organisms as Insecticides. [Author's abstract of paper read before the A. A. A. S. at Washington.] (Scientific American, Supplement, Oct. 31, 1891, v. 32, p. 13206.)

Different classes of experiments referred to: those made with yeast and yeast ferments; those with true bacterial diseases; those with Entomophthora and Isaria; and those with protozoan diseases. The experiments conducted by the Department of Agriculture gave negative results. Those in Kansas are likely to lead to disappointment owing to lack of scientific accuracy of statement and conclusions. Considers the subject important and promising, but emphasizes its difficulty and complication, and the necessity that experimentation be accompanied by fuller knowledge and conducted according to accurate scientific methods.

SNOW, F. H.—Chinch-bugs. Experiments in 1890 for Their Destruction in the Field by the Artificial Introduction of Contagious Diseases. (Seventh Biennial Rep. Kan. State Bd. Agr., v. 12, 1889–90, p. 184; Quart. Rep. Kan. State Bd. Agr., March 31, 1891, p. 113.)

A *resumé* of experiments and reports. The three diseases observed among chinch-bugs said to thrive best in June, July, and August, the bacterial one being best adapted to dry seasons and the white fungus flourishing only in wet weather. Disavows extravagant newspaper claims for this method.

SNOW, F. H.—Experiments for the Destruction of Chinch-bugs in the Field by the Artificial Introduction of Contagious Diseases. (Insect Life, v. 3, No. 6, March, 1891, p. 279.)

Essentially the same *resumé* as that above referred to, giving letters from farmers illustrating the favorable light in which they regard the experiments conducted in their fields. Of the three diseases identified in the laboratory experiments, that produced by the Trichoderma [Isaria] was found there most fatal. In subsequent discussion (see Riley, Webster, Cook, and Fletcher, following), says he does not think that the germs of fungous disease will live over winter in ordinary outdoor conditions.

SNOW, F. H.—Insects Injuring Kansas Wheat. (Rep. Kan. State Bd. Agr., for month ending April 30, 1891, p. 7.)

Not seen.

Snow, F. H.—Second Monthly Report to Official State Paper, as required by law. (Topeka Daily Capital, May 15, 1891.)

Not seen.

Snow, F. H.—Third Monthly Report to Official State Paper, as required by law. (Topeka Daily Capital, June 17, 1891.)

Not seen.

Snow, F. H.—Fourth Monthly Report to Official State Paper, as required by law. (Topeka Daily Capital, July 17, 1891.)

Not seen.

Snow, F. H.—Fifth Monthly Report to Official State Paper, as required by law. (Topeka Daily Capital, Aug. 18, 1891.)

Not seen.

Snow, F. H.—Sixth Monthly Report to Official State Paper, as required by law. (Topeka Daily Capital, Sept. 26, 1891.)

Not seen.

Snow, F. H.—The Chinch-bug Disease and Other Notes. (Insect Life, v. 4, Nos. 1 and 2, Oct., 1891, p. 69.)

A brief *resumé* of his work in Kansas in 1891 on the artificial dissemination of contagious disease among chinch-bugs. The year's experiments in wheat fields as contrasted with those of 1889 and 1890 in corn fields said to indicate that the massing of bugs on hills of corn is more favorable to the successful workings of the disease. Young bugs found as susceptible as old ones. As a result of trip through seven counties in the bug-infested belt an intelligent field agent reports eighty per cent. of the seventy-two experiments successful.

Empusa and Sporotrichum said to develop side by side in the laboratory "infecting cages," and dead bugs from field show both fungi and almost always Micrococcus. Another, larger, Micrococcus often present in dead and dying chinch-bugs.

Outcome of the year's work considered highly encouraging. Results with cultures briefly noted.

Snow, F. H.—Seventh Monthly Report to Official State Paper, as required by law. (Topeka Daily Capital, Nov. 1, 1891.)

Not seen.

Snow, F. H.—Eighth Monthly Report to Official State Paper, as required by law. (Topeka Daily Capital, Nov. 29, 1891.)

Not seen.

Walker, Philip.—The Grasserie of the Silkworm. (Insect Life, v. 3, Nos. 11 and 12, Aug., 1891, p. 445.)

Mentions the prevalence of *grasserie* in the United States in 1890. Thinks Pasteur underrated its importance. Known to American silk-raisers as jaundice. Descriptions of the external and internal symptoms and effects of *grasserie* are given (translated from French authors), followed by technical matter concerning the nature of the characteristic granules of the disease, and a discussion of the different theories as to its cause. Thinks Prof. Forbes is right in considering it bacterial, and quotes from him on this point.

WEBSTER, F. M.—[Means Suggested for the Outdoor Continuance of the Entomophthora from Year to Year, etc.] (Insect Life, v. 3, No. 6, March, 1891, p. 285.)

Thinks spread of Entomophthora "entirely dependent upon atmospheric conditions, and that the chinch-bug disease due to it might be continued from year to year by massing the bugs on small patches of some favorite food plant, as millet, where they are to be infected and destroyed, and then growing upon this ground some crop to which the bugs are partial the next year. In this manner the bugs the following year accumulate on the ground where the germs are most abundant, and most favorable natural conditions would be offered for starting the disease when proper atmospheric conditions were present." Does not consider actual contact necessary for the communication of the fungous diseases, nor corn fields favorable situations for their spread.

1892.

FORBES, S. A.—Bacteria Normal to Digestive Organs of Hemiptera. (Bull. Ill. State Lab. Nat. Hist. v. 4, p. 1.)

Historical account of discovery of cœcal appendages of Hemiptera and of observation of bacteria in such appendages. Full description of the appendages in various families of Hemiptera, and mention of invariable occurrence of bacteria in them, other organs of insects being free from such infection.

FORBES, S. A.—The Chinch-bug in Illinois, 1891-1892. (Bull. Ill. Agr. Exper. Station, No. 19, 1892, p. 48.)

Use of contagious insect diseases still in the experimental stage, relations to weather conditions, particularly, being as yet doubtful. Promise sufficient, however, to warrant thorough and careful experiment.

FORBES, S. A.—[The Work of the Year on the Contagious Diseases of Insects.] (Insect Life, v. 5, No. 1, Sept., 1892, p. 68.)

Notes the advantage which several plant parasites of insects have over insect parasites in that they may be "bred and multiplied enormously without the use of the insect body as a medium, and scattered broadcast where and when most needed." Mentions important work done during the year on *Isaria densa* or *Botrytis tenella,* and also on *Sporotrichum globuliferum.* The latter has been the subject of extensive field experimentation by Prof. Snow; has been demonstrated by Prof. Roland Thaxter (1891) to be readily cultivable on agar; and has been under almost continuous observation and a subject of experiment at the Illinois State

Entomologist's office since May 11, 1891. The manner in which the Sporotrichum penetrates its living host and develops there is described, and the dried ripe conidia are said "to be proof against at least ordinary winter temperatures and against summer heat of 104° Fah." The virulence of the disease varies according to the kind of insect attacked, "the resisting power of the individual, the condition of the weather, and apparently also to some extent according to the previous history of the spores." Gives mode of cultivating and preserving the fungus.

Artificial cultures of *Botrytis tenella* received from Parisian chemists were much less effective than Sporotrichum for the white grub and other insect larvæ.

Mentions Prof. Snow's use of the so-called gray fungus (*Empusa aphidis*) disease of the chinch-bug, with other diseases, for the wholesale destruction of chinch-bugs in the fields. He says of this fungus: "It is incapable of artificial culture, but may perhaps be kept in hand alive in relatively small quantity by using hothouse plant-lice as a medium." Calls attention to a special difficulty attending the study of the bacterial diseases of Hemiptera, and to the establishment of a particular point during his investigations this season. Special reference is made to Prof. Snow's "remarkably extensive, suggestive, and thoroughly conscientious work."

Believes that neither botanists nor entomologists will be satisfied until the subject of insect diseases is thoroughly investigated according to the "strictest methods of experimental science." He says, "Without these we should presently find ourselves swamped by a mass of errors or dubious results which could best be disposed of by leaving them on one side as hindrances rather than helps to progress" Emphasizes the necessity of guarding the agricultural public against a "too eager appropriation of unverified results"—thus bringing the subject into discredit—and against the tendency "to trust the safety of a crop prematurely to this method to the neglect of other more certain but more expensive measures."

SNOW, F. H.—Contagious Diseases of the Chinch-bug. (First Ann. Rep. Direc. Kan. Univ. Exper. Station, 1891.)

A brief *resumé* of work done in 1888, 1889, and 1890, followed by a discussion of the observations and experiments of 1891. This report is too voluminous for abstract here, but its scope is indicated by the following list of its principal headings: General Notes and Results, Laboratory Observations and Experiments, Report of the Field Agent, Reports from Field Experimenters, List of Field Experimenters making Reports, Summary of Field Experiments, Summary of Estimates of Crops saved, Map showing Distribution of Field Experiments and Results, Meteorological Conditions and the Chinch-bug, History of the microphytous Diseases of the Chinch-bug in the United States, Bibliographic Record [of his own publications], Statement of Expenditures, and Directions for obtaining and applying Infection. There are also plates of Micrococcus, Sporotrichum, and Empusa.

Snow, F. H.—Experiments for the Destruction of Chinch-bugs by Infection. Address as retiring President of the Cambridge Entomological Club. (Psyche, v. 6, No. 191, March, 1892, p. 225.)

Calls attention to the difference between his own experiments and those of Prof. Forbes, the latter using artificial cultures for the communication of disease, and he making the chinch-bug itself the vehicle; mentions experiments of Dr. Lugger, in 1888, in Minnesota; and discusses at length his own work on this subject, which began in June, 1889, with *Empusa aphidis* (called an Entomophthora by Prof. Forbes). In field and laboratory exposure of healthy chinch-bugs to bugs dead with this fungous disease "was invariably followed by the death of the exposed ones in from eight to twelve days." Finds this and the Sporotrichum disease most destructive in damp weather, while the bacterial disease (*Micrococcus insectorum*) thrives best in time of drought. Presents statistics (based largely on farmers' reports, but also to some extent on the personal observation of himself and a field agent) concerning field experiments, giving 75.6 as the per cent. of successful ones. 1,222 of these reports were received from Kansas farmers, and 68 from other states and territories. Then follows an outline of laboratory work with the Sporotrichum and Empusa diseases. The infection jars and cases and the method of stocking and restocking them are described, and culture experiments with both Sporotrichum and Empusa are noted, together with features of their characteristic growth. Those with the Sporotrichum resulted in pure cultures (with which, however, only unsuccessful attempts were made to inoculate chinch-bugs), but no spores of Empusa developing, opportunity was wanting for the inoculation of chinch-bugs with pure cultures of that fungus.

Several letters from Kansas farmers are appended as samples of the reports sent in from the field, and an estimate of the actual money value of the experiments in 1891 is given.

1893.

Forbes, S. A.—[Notes of Experiments with *Isaria densa.*] From Presidential Address given at the Fifth Annual Meeting of the Association of Economic Entomologists. (Insect Life, v. 6, No. 2, Dec., 1893, p. 63.)

Has noted during the year but one item of special interest on the fungous diseases of insects, namely, "an unsuccessful experiment to destroy the American white grub by means of Giard's *Isaria densa.*" (See Riley, 1893, "Experiments with the European White Grub Fungus.") Mentions his own "moderately successful" laboratory experiments on various species of white grubs in 1892 with *Isaria densa*; but reports as unsuccessful attempts to communicate the disease by placing diseased grubs in the earth with healthy ones.

Mally, F. W.—Report on the Boll Worm of Cotton (*Heliothis armigera* Hubn). (U. S. Dept. Agr., Div. Ent., Bull. No. 29, p. 59.)

An account of experiments to determine the practicability of utilizing the germs of insect disease for the destruction of the boll-worm. Methods and special apparatus described, and details of observations and experiments given. Beside the boll-worm disease one of *Plusia brassicæ* and one of *Pieris rapæ* were under observation, and as the boll-worm was constantly exposed to infection from these cabbage insects difficult complications existed, necessitating special experiments to determine the nature of the germ causing disease in the boll-worm. These are given in detail. The habits of the boll-worm, whether feeding upon corn or cotton, are such as to reduce to a minimum the chance of dissemination of the disease to which it is naturally subject, and also to some extent account for the failure of the diseases of *Pieris rapæ* and *Plusia brassicæ* to destroy it. The climatic conditions in Louisiana are also thought to account in part for the moderate virulence of the Pieris germ, high temperatures being known to have a devitalizing effect on many bacteria. The Plusia disease, on the other hand, is less virulent in cooler districts. Actual experiment only can justify the assertion that a disease artificially produced in one species may be communicated in the same manner to another. The experiments seem to indicate that the germs studied are facultative rather than true parasites; that is to say, that certain conditions and environment are necessary to their development as parasitic organisms. The failure of such germs to produce economically important results when artificially introduced, should not weight against the availability of strictly parasitic organisms for economic ends. In conclusion, it is emphasized that "the biological and physiological properties of the germs, together with their environments, should first be studied and determined upon a purely scientific basis, without regard primarily to the attainment of practical results.

Riley, C. V.—Experiments with the European White Grub Fungus. (Rep. [U. S.] Sec. Agr. for 1892, p. 163.)

Mention of experiments by foreign investigators which indicate that *Botrytis tenella or Isaria densa* is the best fungus for practical use in disseminating disease among the larvæ of the European white grub (*Melolontha vulgaris*), Dufour's experiments indicating, however, that the "larger percentage of treated larvæ resist the disease even in the laboratory, while in the field the proportion of affected larvæ is considerably less." Spores of this fungus received from Paris were used by Prof. Herbert Osborn at Ames, Iowa; by Prof. Lawrence Bruner at Lincoln, Nebraska; and by Mr. F. W. Mally at Washington, but the results were all unfavorable.

Snow, F. H—Contagious Diseases of the Chinch-bug. (Second Ann. Rep. 1891, Direc. Kan. Univ. Exper. Station.)

General notes and results of the observations and experiments of 1892; laboratory notes, reports of Field Agents, and forty-page list of field experimenters in Kansas who have made report. Directions for obtaining and supplying the chinch-bug infection are given as an appendix.

Webster, F. M.—Insect Foes of American Cereals, with Measures for Their Prevention or Destruction. (Insect Life, v. 6, No. 2, Dec., 1893, p. 146; Bull. O. Agr. Exper. Station, No. 51, p. 130; Twenty-fourth Ann. Rep. Ent. Soc. Ont., 1893, p. 88.)

Says that the fungoid and bacterial parasites of the chinch-bug "will be found available during some seasons and within a certain limit," there being a possibility of rendering them locally and temporarily more effective by persistent artificial cultivation and distribution. The irregularity of outbreaks a feature which prevents the ordinary farmer from using means of protection. Small plats of millet or Hungarian grass are suggested as lures for the deposit of eggs, since they would facilitate the use of vegetal diseases, the insects being here better controlled than in the fields of ordinary cultivation. Corn fields said to be next in value, as the young must there, of necessity, congregate in compact masses. Should be some central station for the supply of infection material.

Webster, F. M.—Observations on some Entomophthoræ. (Journ. Cincinnati Soc. Nat. Hist., v. 15, p. 173; also printed as separate.)

Popular account of casual observations in Ohio of what was supposed to be *Empusa muscæ* infecting flies outdoors, and mention of the almost total extermination of *Phytonomus punctatus* by *Empusa sphærosperma*. Note of *Empusa pachyrrhinæ* (named provisionally) infesting a species of Pachyrrhina; and of *Empusa aulicæ* attacking the fall brood of larvæ of *Spilosoma virginica* under circumstances that insure wide dissemination of the disease, the method of infection also being discussed. As an illustration of the rate of development of the hypha of germination, the effect of an Empusa upon *Diedrocephala mollipes* is mentioned. The use of the name Empusa generically in entomology is said to have priority over its botanical use.

1894.

Atkinson, G. F.—Artificial Cultures of an Entomogenous Fungus. (Bot. Gaz., v. 19, April, 1894, p. 129.)

Notes the finding of a specimen of *Isaria farinosa* upon an arctid chrysalis, describes the fungus, and gives technical account of its different forms of growth on various media. Suggests that, following Tulasne, "perhaps varying the substratum and other conditions of environment might result in the development of the Cordyceps form in artificial cultures from the Isaria stage."

BRUNER, LAWRENCE, and BARBER, H. G.—Experiments with Infectious Diseases for combating the Chinch-bug. (Bull. Neb. Agr. Exper. Station, No. 34.)

Brief account of measures taken in Nebraska for the propagation and distribution of the white-fungus disease (*Sporotrichum globuliferum*) by means of chinch-bugs dead with this disease obtained from the Kansas University Station. Methods practically the same as those followed by Prof. Snow, who is quoted at length on chinch-bug diseases due to *S. globuliferum*, *Micrococcus insectorum*, and *Empusa aphidis*. Recent observations said to indicate that chinch-bugs are sometimes killed by another form of the Sporotrichum, in which none of the characteristic external fungous growths appear. List of one hundred and sixty-four farmers to whom diseased chinch-bugs were sent, about twenty-five per cent. of the sendings leading to successful experiments.

DAVIS, G. C., and WHEELER, C. F.—[A Fungous Disease of the Larvæ of the Clover-Leaf Weevil (*Phytonomus punctatus.*)] (Bull. Mich. Agr. Exper. Station, Oct., 1894, No. 116, p. 50.)

A letter from a Cass county (Michigan) farmer is given, in which he reports the occurrence of a very destructive fungous disease which periodically destroys this insect, and which in the spring of 1894 prevailed from Wisconsin to West Virginia. In the case here reported cattle feeding upon the clover were temporarily poisoned. The fungus causing the epidemic is *Empusa* [*Entomophthora*] *sphærosperma*, known to infest the larvæ of many other insects. Brief mention is made of the characteristic growth of the fungus and its effect upon the larvæ of the clover-leaf weevil.

FORBES, S. A.—The Chinch-bug in Illinois, 1894. (Press Bull. No. 16, June 9, 1894, Ill. Agr. Exper. Station.)

Offers cultivated Sporotrichum to farmers for experimental distribution in infested fields. Results of this method insufficient to warrant entire dependence upon it. Should be made only one feature of a general campaign.

GARMAN, H.—Observations on Farm Pests. (Third Ann. Rep. Ky. Agr. Exper. Station, p. 9.)

On p. 25 notes an epidemic disease of the grain louse (*Siphonophora avenæ*) caused by a species of Empusa (*E. planchoniana*), and mentions two other species of the same genus—one probably new to science—which he has observed attacking plant-lice indoors. Symptoms and *post-mortem* condition of the infested grain lice briefly indicated. Wet weather or damp situations said to greatly favor the development of parasitic fungi.

Webber, H. J.—Preliminary Notice of a Fungous Parasite on *Aleyrodes citra* R. & H. (Journ. Mycol., Vol. 7, p. 363.)

Announces his discovery of a fungus—provisionally identified as *Aschersonia tahitensis*—which is parasitic on larvæ and pupæ of *Aleyrodes citri* in Florida, and which, it is thought, may prove of economic value. An Aschersonia (probably the same as the above) has likewise been found in Florida "growing in considerable abundance on a waxy scale (Lecanium) of the sweet bay tree."

Forbes, S. A.—Chinch-bug Experiment. (Special Bull. Ill. Agr. Exper. Station, June 30, 1894.)

Reiterates with emphasis that too much dependence should not be placed on infection method for destruction of chinch-bug. Long experience establishes the fact that chinch-bug diseases cannot be expected to spread in very dry weather, consequently most likely to fail when help is most needed.

Forbes, S. A —How to fight Chinch bugs. (Prairie Farmer, Aug. 4, 1894, v. 66, p. 2.)

Introduction of contagious disease at best an uncertain operation, and practically sure to fail absolutely in very dry weather. Regarded at most as an interesting experiment, not yet to be depended on in practice.

Forbes, S. A. The Chinch-bug in 1894. Prospect for 1895. Contagious Disease Experiments. Other Experiments. Plans and Recommendations for next Year. (Bull. Office State Ent. Ill., No. 5.)

Preliminary account of work of the season of 1894 with contagious diseases of the chinch-bug and other insects, due to Sporotrichum. Discussion of results of experiments. Proposed supply of infection material.

Forbes, S. A.—General Record for 1891 and 1892. (Eighteenth Rep. State Ent. Ill, p. X.)

Reports occurrence of "white fungus" of the chinch-bug in Northern Illinois (not in southern) in fall of 1891 and spring of 1892, but only where local rains gave it an opportunity for development. Numerous requests received from farmers for infected specimens for use in their fields." "Although convinced by my previous observations of these diseases and by laboratory and field experiments conducted by us, but not yet reported, that there was under the circumstances existing very little probability of a valuable outcome to these experiments, I did what I could to supply the spontaneous demand by making artificial cultures and sending out both spores and infected insects. Every such sending was, however, accompanied with a warning intended to prevent the recipient from taking the experiment too seriously, believing, as I did, that harm was likely to result from a dependence upon this still problematical method to the neglect of older and more laborious and costly precautions.

Forbes, S A.—The Corn Root Aphis (*Aphis maidiradicis*, Forbes). (Eighteenth Rep. State Ent. Ill., p. 74.)

Entomophthora fresenii infesting sexual generation of root aphis of corn found on *Rumex crispus*. Disease characterized by this fungus generally distributed in field.

Forbes, S. A.—The White Grub. Genera Lachnosterna and Cyclocephala. (Eighteenth Rep. State Ent. Ill., pp. 126 and 133.)

Statement concerning diseases of white grubs characterized by Cordyceps and Sporotrichum. Mention also made of Isaria infesting white grubs of Europe.

Elaborate account of experimental work with parasitic fungi of white grubs. Species used were *Botrytis tenella*, *Isaria leprosa*, and *Sporotrichum globuliferum*.

Forbes, S. A. The Southern Corn Root Worm (*Diabotrica 12-punctata*, Oliv.). (Eighteenth Rep. State Ent. Ill., p. 150.)

Reference to bacterial parasite of larvæ of *Diabrotica 12-punctata*, with technical description of species under name of *Bacillus rufans*, n. sp.

Kellogg, V. L.—A European Experiment with Insect Diseases. (Third Ann. Rep. Direc. Kan. Univ. Exper. Station, 1893, p. 227.)

Summary of an article by A. Giard* reporting his investigations of *Isaria densa*, a parasite of the European May beetle, together with mention of some other European parasites of insect larvæ, including two bacterial species (*Bacillus septicus*, Krass., and *B. tracheitus* or *graphitosis*, Krass).

Snow, F. H.—Contagious Diseases of the Chinch-bug. (Third Ann. Rep. Kan. Univ. Exper. Station, 1893.)

Exhibits the results of experiments for the destruction of chinch-bugs by the artificial introduction of disease among live bugs in the field during the season of 1893. A list of all farmers from whom reports have been received is given, and, as far as possible, an extract is presented from each report giving the outcome of the experiment. States also results of scientific investigations in the University laboratory concerning the life history of the white fungus (Sporotrichum).

Webster, F. M.—Vegetal Parasitism among Insects. (Journ. Columbus Hort. Soc., April, 1894; also published as a separate.)

A partial reprint of matter published under title "Observations on some Entomophthoræ" and of extracts from Bulletin 22 of the U. S. Department of Agriculture, Division of Entomology, with brief discussion of the specific identity of the chinch-bug fungus currently known as *Sporotrichum globuliferum*, and comment upon

* "*L'Isaria densa* (Link) Fries, champignon parasite du hanneton commun, (*Melolontha vulgaris*, L.)." (Bull. Sci. de la France et de la Belgique, tome XXIV.)

Prof. Snow's experiments. A classified list of entomophytes of the families Hypocreaceæ and Entomophthoraceæ is given, with three plates of illustrations.

WEBSTER, F. M.—The Economic Value of Parasitism. (Twenty-fifth Ann. Rep. Ent. Soc. Ont, p. 53.)

A brief discussion of the general subject of the parasitism of insects. *Entomophthora sphærosperma* said to have saved the hay crop in Ohio in 1894 by completely checking an enormous outbreak of the clover-leaf weevil (*Phytonomus punctatus*). Parasites when not numerically strong must be assisted in their work by insecticides; and entomologists must learn to detect the exceptional cases where parasites are likely to fail in overcoming a destructive insect, and by artificial methods supplement their lack of numbers.

LABORATORY EXPERIMENTS WITH CHINCH-BUGS.

If the chinch-bug were practically constant in its numbers year after year, its regular annual appearance would be foreseen and might be generally provided against; but it increases and decreases with an irregular periodicity whose causes are not yet fully understood, and which therefore embarrasses prediction and makes certain prevention impossible. It is therefore an important part of the problem which the injuries of this insect impose upon the agriculture of the State to ascertain the conditions precedent to its enormous outbreaks and to its almost total disappearances.

For the purpose of getting exact information on these points I detailed, in July 1894, Mr. W. G. Johnson, one of the assistants of the State Laboratory of Natural History under my control, for continuous experimental investigation, to be carried on in my office insectary. This work was thoroughly done, under my own general supervision, and the results here reported are a definite addition to our knowledge of the habits, capacities, and relationships of this insect.

The rapid increase of the chinch-bug under favorable circumstances is of course dependent primarily on its normal breeding rate, but just what that rate is has not hitherto been precisely ascertained. It has been commonly asserted, indeed, since 1867* that the number of eggs deposited by a single female is about five hundred, but this was a mere estimate based on general field observations made in 1865 by Dr. Henry Shimer of Mt Carroll, Illinois. On this point Shimer says, "The parent chinch-bug is occupied about twenty days in laying her eggs, during which time she probably lays about five hundred eggs and then dies."

From Mr. Johnson's report of the experiments above mentioned we learn that a single female chinch-bug kept under the most favorable conditions may deposit as many as two hundred and thirty-seven eggs, but probably few, if any, more; that the egg-laying period lasts about forty days, or double the number above given; that pairing takes place, in the summer generation, from four to five days after the female sheds her pupal skin; that the first eggs are laid in two or three days after pairing, six to eight days after the pupal skin is cast; that the average length of life of the adult female of the summer generation is about fifty days, and that of the male about seventy-eight days; that the female pairs very frequently, perhaps every day, during the egg-laying

* Proc. Acad. Nat. Sci. Phil., 1867, p. 79.

season; and that the eggs may hatch in from eighteen to twenty-one days after deposition, or an average of about twenty days*.

The *disappearance of the chinch-bug* after a season of extraordinary abundance is most commonly attributed to the immediate effect of wet weather, and no general idea concerning its economy is more firmly fixed then the supposition that even ordinary summer rains will destroy it outright Nevertheless, no precise investigation of its ability to endure submergence has ever been reported, and this supposition is really based on superficial observation. The results of our experiments on this point may be summed up as follows:

Chinch-bugs just emerged from the egg will survive a *complete immersion* of one to three hours; young of the first molt, three to five hours; of the second molt, six to nine hours; and of the third molt (pupæ) eight to thirteen hours. Adults of the summer generation will live under water from twelve to twenty-two hours, and those of the fall generation have revived after thirty to fifty-four hours complete submergence.

Chinch-bugs just emerged may live *floating on the surface* of water seven hours, while those of the second molt may revive after twenty-three hours. Bugs of the second molt have lived two and a half days under such conditions; those of the third molt (pupæ), three and three fourths days; and adults, about fifteen days. Chinch-bugs have even molted while in this situation, the wings and crust of the adult hardening, as if the insect were free.

In the first article of this report I have described experiments showing the fatal effect on chinch-bugs of *exposure to the heat of the sun* in the dry dust of furrows made as a check to their movements from one field to another. These experiments did not enable us, however, to discriminate the part of this effect due to the heat of the dust from the part due to its physical condition. I consequently arranged a series of three laboratory experiments with chinch bugs in confinement, in one of which the bugs were kept without food in bottles otherwise empty, in another of which they were kept on moist earth, while in a third they were shut up in bottles of dry dust. All were placed in the shade at the normal temperature of the season.

It was ascertained in this way that cool dry dust had a decided insecticide effect, bugs of the two youngest stages dying in it within twenty-four hours, but older ones living from one to six days, according to their age, while the other lots in confinement lived from eight days for the youngest to forty days for the longest-lived adults.

The details of observation on which the foregoing general statements are based are given in the following personal report by Mr. Johnson:

MR. JOHNSON'S REPORT OF EXPERIMENTS.

SIR:—The following is my report on some experiments with chinch-bugs made according to your direction during the season

* In earlier experiments I have found eggs to hatch in fifteen days after they were deposited (see my Fifth Report, p. 44), and experiments made in my office during the year 1895 demonstrate that the incubation period may vary from twelve to twenty-two days.

of 1894. Although the primary object of the egg experiment was to determine the number of eggs deposited by a female, several other points relative to the life history of this insect have been cleared up by it.

The immersion experiment, though fairly satisfactory, was conducted with no little difficulty, as many of the immersions, especially of adults, necessitated frequent examination during the late hours of the night. The floating and confinement experiments were conducted at the same time.

EGG EXPERIMENT.

As the primary object of this experiment was to determine the number of eggs deposited by a single female, the bugs were selected with great care. A quantity of them were collected from corn on the Agricultural Experiment Station grounds July 18 and brought to the insectary. Males and females just emerged from the pupal stage, still retaining the yellowish or bleached appearance characteristic of chinch-bugs which have recently molted for the last time, were selected and placed on the Setaria in the cages. These consisted of six ordinary five-inch flower pots filled with carefully screened garden soil, free from sand and particles of foreign material, in which a plant of fox-tail grass (*Setaria glauca*) had been set July 14, four days prior to the admission of the chinch-bugs. Each plant was then covered with a common three-inch flint-glass lamp chimney with smooth top, over which a piece of Swiss muslin was drawn and kept in place with a strong rubber band a quarter of an inch wide. One of these cages is represented in Plate XI.

Six such cages were stocked July 18.

No. 1 was started with a single female and two males, but owing to an accident one male escaped July 22. It will be seen from the table following that the female in this cage produced the greatest number of eggs, laying two hundred and thirty-seven from July 24 to September 4, thus averaging a little more than five eggs per day. I am of the opinion, however, that a chinch-bug does not deposit its eggs every day, but at intervals of three to five days.

The total number of eggs taken from behind the leaf sheaths of the Setaria was one hundred. These were usually behind sheaths near the ground, and were deposited in clusters, ten to fifteen eggs being often attached side by side. One hundred and twelve were taken from the ground at depths varying from one eighth to three fourths of an inch. They were usually found singly; very rarely in clusters. They were scattered indiscriminately in the earth in the cage, the greatest number, however, being among the roots near the base of the plant. Twenty-five young bugs were also removed from the cage. These were from eggs that had been overlooked, or that were so placed behind leaf sheaths that they could not be removed without injuring the plant. The eggs were taken out of this cage every four to six days, care being taken each time to remove the parent insects before the examination was made. The plant was kept trimmed and in a healthy and vigorous condition. The female lived as an adult from July 18 to September 8—a period of fifty-two days—while the death of the male did not occur until October 5, or seventy-nine days after the last molt.

No. 2 was prepared like No. 1 and at the same time. The insects remained in good condition throughout the entire period of the experiment. The total number of eggs deposited by the female was two hundred and thirty-three, or four less than the total from No. 1. The egg-laying period was the same in both cases. One hundred and fifty-one were taken from behind the leaf sheaths near the base of the plant, usually in clusters, and seventy-three were collected from the earth, this being thirty-nine less than were taken from similar situations in No. 1. The conditions of both cages were as nearly alike as they could be made, with the exception of the number of males in each, there being one in No. 1 and two in No. 2. The eggs from the earth were found scattered more or less about the cage at depths ranging from one eighth to three fourths of an inch. They were most abundant near the base of the plant, on the roots. Eight young bugs were removed; two August 12, three August 21, and three September 9. The cage was examined August 12, 16, 21, 25, September 1 and 9, and October 7. On the final examination, October 7, one bug in the second molt was removed from the plant. The grass was kept in good growing condition. The female lived fifty-three days, counting from the time of maturity, or from July 18 to September 9. One male lived until October 3—seventy-seven days—and the other until October 7, or eighty-one days after maturity.

No. 3 contained a single female and three males. This experiment came to an untimely end August 21, when all the insects escaped through an opening at the bottom of the cage caused by the settling of the earth in the flower pot. Fifty-two eggs were removed August 13, twenty-four from the plant and twenty-eight from the earth. Twelve eggs and two young bugs were removed August 16, and twenty-five eggs and four young were taken out August 21. This cage was kept in good condition and examined several times afterwards. One young bug was removed September 1, making a total of ninety-six eggs deposited by the female up to the time of escape. The number of eggs removed from Nos. 1, 2, and 6 to August 21 is as follows: No. 1, 107; No. 2, 129; No. 6, 69.

No. 4, like No. 3, contained one female and three males. A careful watch was kept of this experiment, but none of the eggs were removed. One male died July 20. The first eggs were observed July 25, and the first young August 15. The insects were seen pairing each day the observations were made. Fresh food was supplied from time to time as the bugs increased in number and matured. One hundred and thirty-four insects, including all stages of development, were removed October 3. The parent female died September 7, having lived fifty-one days after casting its pupal skin. It was forty days depositing its eggs. The two remaining parent males were still alive when the experiment was closed.

No. 5 contained a single female and four males. The first eggs were observed July 25, and the first young bugs appeared August 15, a period of about twenty days from the time the eggs were deposited. The insects were seen pairing each day the experiment was observed, usually all the males being clustered about the female. The eggs were left in the cage, where they hatched, the insects being removed October 8. Ninety-eight bugs in all stages of development were taken out at this time. The parent female died September 4, having lived just forty-eight days from the time of confinement. She was thirty-eight days depositing her eggs. Three of the old males were alive when the cage was set aside, and one was found dead on the ground.

No. 6 was prepared like No. 5, and contained one female and four males. The first eggs were observed July 26, and the first young bugs appeared August 16, or about twenty days from the time the eggs were deposited. The insects were seen pairing each day observations were made, the males usually clustering about the female. Thirty-eight eggs were removed from the grass and thirty-five from the ground. Forty-three young were also removed, making the total number of eggs laid, one hundred and sixteen. The female died September 6, having lived a period of fifty days in confinement. The egg-laying period was thirty-eight days. One male died Ooctober 1, having lived seventy-five days from the time of the last molt. Another male died October 3, being seventy-seven days old as an adult, and two others died October 6, having lived eighty days.

The following table gives the foregoing facts in a condensed form:

TABULAR EXHIBIT OF OBSERVATIONS.

Cage No	No. of females.	No. of males.	Placed in cage.	First pairing.	First eggs deposited.	First eggs hatched.	Total No. of eggs deposited.	No. of days laying eggs.	Female died.	Males died.	Days female lived.	Days male lived.
1	1	2	July 18.	July 22.	July 24.	Aug. 13.	237	42	Sept. 8.	1, Oct. 5 (1 escaped July 22.)	52	79
2	1	2	July 18.	July 22.	July 25.	Aug. 12.	223	42	Sept. 9.	1, Oct. 3. 1, Oct. 7.	53	77 81
3	1	3	July 18.	July 23.	July 26.	Aug. 16.	(Up to Aug. 21) 96.	——	(Escaped.)	—— ——	——	——
4	1	3	July 18.	July 22.	July 25.	Aug. 13.	134	40	Sept. 7.	1, July 20 (2 put in alcohol alive Oct 3).	51	77
5	1	4	July 18.	July 22.	July 25.	Aug. 15.	98	38	Sept. 4.	1, Oct. 8 (3 put in alcohol alive).	48	77
6	1	4	July 18.	July 22.	July 26.	Aug. 16.	116	38	Sept. 6.	1, Oct. 1. 1, Oct. 3. 2, Oct. 6.	50	75 77 80

IMMERSION EXPERIMENT.

I began an experiment August 4, 1894, to ascertain the length of time for which bugs of the first annual generation could endure complete immersion in water without perishing. A miscellaneous lot of bugs of all ages was collected from corn on the University Experiment Station grounds and brought to the insectary. Half a dozen, representing each of the various stages of development, were selected and placed in ordinary one-ounce glass bottles with wide mouth. Adults that had just emerged from the pupal stage were selected and left in the bottles for several hours—until they were fully hardened. Three bottles for each of the various stages were prepared for each separate immersion. A thin layer of cotton previously soaked in rain water was spread over the bottom of each bottle, which was then filled with rain water at a temperature of 70° Fah. The cotton rising to the neck, the bugs could be kept entirely immersed for any definite time desired.

The young, especially the pupæ, sink more readily in water when entirely immersed than adults. I do not believe that adult chinch-bugs would be entirely immersed in water during an ordinary rainfall unless they were entrapped under rubbish or in cracks in the ground or on roots of some submerged plant. It is almost impossible to keep them under water unless some mechanical device is arranged to hold them; while, on the other hand, pupæ kept immersed for a few moments will rapidly sink to the bottom. This difference is owing, no doubt, to the air retained under the wings of an adult. The details of this experiment are given in the following notes:

No. 1. Five lots of young bugs just emerged from the eggs were immersed August 4, as described above. It is probable that they were of the second brood, although I am not certain on this point. This is, however, of little importance, since the hardiness of the young cannot vary much in the two generations. The first lot were immersed at 8:55 a. m. August 4, and were removed half an hour later and placed on a dry towel, where they remained four minutes and then crawled away. The second, third, and fourth lots were similarly immersed for one, two, and three hours respectively, and then placed on the towel. All but three bugs in the one-hour lot and all but seven in the two-hour lot revived in from five to ten minutes after removal from the water, while only four of those which were immersed three hours revived after lying on the towel for fifteen minutes. The fifth lot were immersed four hours, but were lost accidentally while being removed. The attention the other lot required at this time prevented the completion of this experiment. From the above, however, it seems that newly-hatched chinch-bugs cannot withstand immersion much over two hours.

No. 2. Five lots of the first molt were immersed in a similar manner the same day. The first three lots were kept under water two, three, and four hours. All those of the first lot revived in from eight to twelve minutes, and the second lot were crawling about in from twelve to fifteen minutes; but six of the third lot did not revive at all, while those remaining feebly crawled away in from twelve to twenty minutes. The fourth and fifth lots were immersed five and six hours respectively. Only two of the fourth lot revived after being left on the towel for half an hour, while none of the fifth ever moved a leg or antenna. From this it appears that bugs of the first molt cannot withstand complete immersion longer than three to five hours.

No. 3. Five lots of the second molt were similarly immersed for four, five, six, seven, and eight hours respectively. All of the first two lots revived in from twelve to twenty minutes. Five of the third, ten of the fourth, and fifteen of the fifth lots were drowned, while the others crawled feebly about in from fourteen to twenty-two minutes. Two more lots were selected and immersed, one for nine hours and the other for ten. Only two of the sixth lot survived the treatment, and all of the seventh lot succumbed and never moved after being taken out. From the above it appears that chinch-bugs of thesecond molt cannot withstand complete immersion longer than six to nine hours.

No. 4. August 10, eight lots of the third molt, or pupæ, were immersed for seven, eight, nine, ten, eleven, twelve, thirteen, and fourteen hours. All those of the first lot and all except seven in the second revived in from twelve to thirty minutes; eleven in the third lot did not recover; and twelve, or two thirds, of those in the fourth lot were dead when removed, showing no signs of life after remaining on the dry towel for one hour. In the fifth and sixth lots there was a reversion of things. Eight of the fifth lot and nine of the sixth survived the immersion and crawled away. I cannot explain this difference, unless there was a greater amount of air accumulated on the under surface of the cotton in their immersion bottle than in the others. I have noticed that when there was a bubble of air attached to a bug, or to several, they would struggle much longer than the others in the same bottle free from such bubbles. Fifteen of those in the seventh lot and all of those in the eighth were dead when removed. From this it appears that the pupæ are extremely variable, and that they will often survive eight to thirteen hours' immersion.

The six pupæ that survived the ten-hour immersion were placed in a two-ounce wide-mouth bottle and corked up tightly without food. Three adults emerged August 13, and one other emerged August 20. August 27 one adult and one pupa died, and the others died two days later, having lived nineteen days in this cell without food, and without air except that which was corked up in the bottle.

No. 5. August 11 and 12, ten lots of recently molted adults were immersed eight, ten, twelve, fourteen, sixteen, eighteen, twenty, twenty-two, twenty-four, and twenty-six hours. All the insects in the various lots were removed from their respective cages and placed on towels until they were dry. Each lot was then placed in a four-ounce wide-mouth bottle which was afterward plugged with cotton, numbered, and laid on a table, where they were observed. All the insects in the eight- and ten-hour lots revived in twenty to forty minutes and moved about in the bottles at a lively rate; all but two in the twelve-hour lot, and all but two in the fourteen-hour lot revived, and were active in twenty to forty minutes; four from the sixteen-hour lot, and nine from the eighteen-hour lot were dead when removed, all the others reviving and crawling feebly about in twenty to forty minutes; and fourteen from the twenty-hour lot were dead when removed, the others barely showing signs of life but not trying to escape. A single bug in the twenty-two hour lot survived the immersion; but all of those in the twenty-four and twenty-six hour lots were dead when removed. From these facts it appears that adult chinch-bugs of the first generation cannot withstand complete immersion longer than twelve to twenty-two hours, the latter time being about the limit. The bugs which had been immersed ten hours were placed in a four-ounce bottle without food and corked up. Two dead bugs were seen August 25, and several eggs were noticed on the sides of the bottle August 27. They had been deposited several days before, for the young bugs were fairly well matured within. These eggs hatched September 7, and the young bugs lived in this prison-cell for two days. Six more adult bugs were found dead on this date, and all except one had died by the 10th. The last one, a female, died September 12. This is simply given as an example of the wonderful power of endurance these insects possess. From the above it is clear that these bugs lived in these bottles without food and practically without air from fourteen to thirty-one days after having revived from a ten-hour complete immersion in water; and that in the meantime they paired and produced eggs from which young emerged that lived two days.

No. 6. On account of pressure of other experimental work these experiments were not repeated with insects of all stages of the second generation, but a long series of immersions was begun September 12, with adults of this generation. The insects were selected with the same care as in the first series, and twelve lots were immersed in a similar way. Beginning with an immersion of twenty-one hours for the first lot, three hours were added for the second, and the time was lengthened at this rate for each successive lot, bringing it up to fifty-four hours for the twelfth, when the experiment was permanently interrupted by more important work. I give herewith in detail the results reached with these adults of the second generation: All the bugs in the twenty-one, twenty-four, and twenty-seven-hour lots revived in from twenty to forty minutes and were very active; in the thirty-hour-lot four bugs did not revive, while the others seemed to be in good condition one hour later; in the thirty-three, thirty-six, and thirty-nine-hour lots the dead insects numbered respectively seven, twelve, and thirteen, while the others seemed to be in good condition and were actively moving about in the bottle an hour later; in the forty-two and forty-five-hour lots twelve and fourteen insects died respectively, while the other bugs revived in an hour; in the forty-eight and fifty-one-hour lots the numbers dying were respectively fourteen and fifteen, the other insects reviving in about half an hour and crawling about the bottle; and in the fifty-four-hour lot only three bugs survived the treatment, but these were lively and making attempts to escape at the expiration of that time.

FLOATING EXPERIMENT.

This experiment was begun August 3, 1894, with chinch-bugs collected from the same field as those used in the immersion experiment. Bugs in various stages of development were selected and floated on the surface of rain water at a temperature of 70° Fah., in ordinary tumblers about two thirds filled.

No. 1. Eighteen bugs just emerged from the egg were selected August 3, divided into three lots of six each, and floated on the surface of water at 8:45 a. m. They swam about for several minutes and then remained quiet as if dead, but when removed on a pencil point crawled away. Each lot was examined every fifteen minutes, and the first dead one was removed at 12:45 p. m. All were dead by 2:45, or seven hours from the time the experiment began.

No. 2. Eighteen chinch-bugs of the first molt were divided into three lots, as above, and floated on the water at 9:15 a. m. They swam about for some hours, but at 5:15 p. m. were quiet. They were examined every thirty minutes, and not until 8:15 p. m. did any fail to crawl away almost immediately after being removed from the water, and then but one. At 11:15 six were very feeble, but they were just alive at 6 o'clock the following morning. None of the insects removed from the water at this time attempted to escape. At 7:15 a. m. eight were removed that showed no signs of life, and these did not revive when placed on a dry towel. At eight o'clock fourteen out of the eighteen were dead, and the remaining four were dead at 8:45. From this it appears that chinch-bugs of the first molt will often remain alive on the surface of water for about twenty-three hours.

No. 3. Three lots of chinch-bugs of the second molt, six in each lot, were floated August 3 at 9:30 a. m. They were exceedingly active, and three escaped an hour later. At 7:30 p. m. they were still active, and at 11:30 were in good condition but quiet. They were next observed at 6 o'clock the following morning, August 4, being then in good conditian and attempting to escape whenever anything was held in the water near them. They were examined every two hours during the day, and were still active at 10 o'clock p. m. When examined the following morning, August 5, at 7 o'clock, they were in fairly good condition. Three more bugs had made their escape thus leaving but twelve under observation. These were examined every two hours, as before, and at 3:20 p. m. four bugs showed signs of weakness. At 5:30 six others were about helpless, and barely moved when taken out of the water. At 7:30 all were dead, five of them having sunk to the bottom, It appears from the foregoing that bugs of the second molt will live for two and a half days on the surface of water.

No. 4. August 3, at 4 p. m., three lots of six pupæ each were placed on the surface of water. They were very active making every effort to escape, and were still swimming at 7:30 p. m. They were next observed August 4, at 6:15 a. m., when they were still active and trying to escape, two having disappeared. They were observed at 10 a. m., 2 p. m., and 6 p. m., being still in good condition. All were active the following day, August 5, at 7 o'clock a. m. Observations were taken, as before, every four hours during the day. At 7 p. m. an adult which had emerged was in good condition, but two pupæ were on their backs, apparently unable to turn over. Two more adults had emerged the following morning, August 6, and were actively swimming about the surface of the water, endeavoring to escape. At 10 a. m. two pupæ were noticed on their backs, and when turned over were soon on their backs again, and an hour later they had sunk to the bottom. The adult that emerged August 5 was dead at this time and was removed. It was plainly visible that the pupæ were weakening. Two more were dead at 2 p. m. and three more at 6 o'clock, leaving only eight alive, and four of these were dead and had sunk to the bottom the following morning (August 7) at 7 o'clock. The other four remained alive until 11 a. m., when all were dead and three of them in the bottom of the tumbler. From this it appears that the average life of pupæ on the surface of water is about three and three fourths days.

No. 5. Eighteen recently molted adults were selected and floated on water on the same day and at the same time as those in No. 4. These bugs, however, were separated into six lots of three each. They were very active when first floated, and three escaped during the night. Those remaining swam freely about the surface of the water August 4, but no more escaped. One, however, had gotten on its back, and when removed at 6 p. m. was about dead. It was removed for a few moments and then replaced, but it was dead the following morning, August 5, when, however, the others were in good condition. These were alive and apparently healthy August 6, and no change was noted the following day. One was found on its back August 8, at 10 a. m, but revived and lived until August 11, 8 a. m. The remaining thirteen insects seemed in good condition August 12, and were alive on the 14th. On the 15th one was noticed to be weakening, but it did not die until the 18th, at which time six more were dead, two of them having sunk to the bottom. The following day, August 19, the others died and were removed. It appears from this experiment that adult chinch-bugs (generation not definitely known) can live on the surface of water about fifteen days, the average for the lot, however, being about thirteen days.

CONFINEMENT EXPERIMENT.

I report here a series of three confinement experiments with chinch-bugs of various ages. They were collected from the same field as those used in the foregoing experiments. From No. 1 it appears that adult chinch-bugs in close confinement in a dry vial are less hardy than the young, the adults in this case having lived only seven days, while the other stages lived eight and nine days. There is some doubt, however, about the age of the adults used in this experiment. They were selected with care, and only those with bright fresh wings were used, but even these may have been several weeks old, and possibly partially spent males and females of the first generation. It appears from the second experiment that newly hatched chinch-bugs and those of the first, second, and third molts, when confined without food in vials partly filled with perfectly dry and finely pulverized earth lived respectively one day or less, two days, and three days, while adults so situated lived six days. This indicates that earth in the above condition is hurtful to chinch-bugs in confinement, the young dying first, and the other stages successively in the order of their age. It is evident from experiment No. 3 that chinch bugs confined in a saturated atmosphere on damp earth will live for a considerable length of time without food, newly hatched bugs living nine days, as did also bugs of the first molt, those of the second molt eleven days, those of the third molt (pupæ) twenty-two days, and adults forty days. Comparing Nos. 1, 2, and 3, it appears that chinch-bugs will live longer in confinement in a saturated atmosphere on damp earth than they will when the earth and air in the vial are perfectly dry, or when the vial contains no earth at all.

The details of the experiments just referred to are subjoined.

No. 1. August 3, eighteen 2-dram vials with corks were provided and grouped in lots of three each. In the first lot three adult females were placed without food, one in each vial. Adult males were placed in the second lot; pupæ in the third; bugs of the second molt in the fourth; those of the first molt in the fifth; and newly hatched bugs in the sixth. The bottles were then corked tight and observed daily. August 4 the bugs seemed to be in their usual condition, and no change was noted on the 5th or 6th. On the 7th one adult female in the first lot was seen to be weakening, but the other insects were in good condition. No change was noted on the 8th, but on the 9th one male and two females were nearly dead, and on the 10th all the insects in the first two lots were dead, having lived but seven days. The other insects seemed at this time in fairly good condition, with the exception of the pupæ, which were sluggish. August 11 the pupæ were all dead; one insect in the fourth lot had died while the other two had molted, being however rather sluggish; all had died in the fifth lot, two of them after molting; and the newly hatched bugs were also dead. On the morning of the 12th the two remaining bugs in the fourth lot were found dead.

No. 2. This experiment was begun August 4, and was conducted like No. 1 except that the vials were about one third filled with perfectly dry and finely pulverized earth, and that the insects were divided into five lots instead of six, male and female adults not being confined separately as before. The adults constituted lot one; the youngest, lot five; and the intervening stages, lots two, three, and four. August 5 all of lots four and five were dead and the third lot showed signs of weakness, but the other insects were in good condition. August 6 all of lot three were dead and the pupæ (lot two) were feeble. The adults seemed in good condition at this time. August 7 all the pupæ were dead and the adults were beginning to show signs of weakness. No change was noted August 8, but August 9 two of the adults seemed very weak, and all were dead August 10.

No. 3. This experiment was begun August 4, and was like No. 2 except that damp earth was placed in the vials. August 5, 6, 7, and 8 the bugs all seemed in good condition. August 9 one bug in lot two and one in lot three had molted, no change being evident in any of the others until August 11, when two of the insects in lot five and one in lot four gave evidence of weakness, and one in the latter lot had molted. August 12 all in the fourth and fifth lots were very sluggish, but no change was noted in the others except that one more of the third lot had molted. August 13 all those in lots four and five were dead, but those remaining were in good condition. August 14 to 16 no change. August 17 one more bug in lot three had molted, and the insects in the remaining lots were in fair condition, the adults especially seeming to be perfectly healthy. August 18 one of the bugs in lot three seemed very weak and sluggish, but the others were not noticeably so. August 19, no special change apparent except that the sluggishness was very marked in lot three, all being dead August 20. The others seemed in good condition at this time. August 21, one in lot two had pupated; August 22 and 23, no change noted; August 24 and 25, two of the pupæ were noticeably sluggish, all dying on the 26th. At this date the adult that emerged from this lot was still alive but sluggish. August 27 the adult in lot two was found dead, but those in lot one were in good condition, remaining so until September 12, at which time the first one was seen to be inactive. One died September 13 and the others were all dead the 15th.

Respectfully submitted,

W. G. Johnson,

Assistant Entomologist.

THE WHITE ANT IN ILLINOIS.

(*Termes flavipes*, Kollar.)

The termites or white ants of Illinois are of interest to the economist chiefly by reason of their injuries to buildings and other wooden constructions of all descriptions, and to collections of books in store-rooms or neglected libraries. They are also capable of doing considerable harm to a great variety of trees, shrubs, and herbaceous plants, but the loss they thus inflict is usually slight and on the whole scarcely sufficient to require serious attention. Apart from their economic relations they are among the most interesting of our native insects, especially because of their remarkable organization in societies and because of many peculiarities of structure, habit, and association connected with their high grade of social development. As among our common ants, which they resemble superficially except in color, the descendants of the same parentage are differentiated into several castes or classes; namely, workers and soldiers (both of which are males and females sexually undeveloped), and fully developed sexes, capable of flight.

These white ants present the most remarkable example known to zoölogists of enormous and perpetual parasitism, the entire contents of the alimentary canal being in fact little more than a gruel of microscopic animal parasites belonging to peculiar species and genera of Protozoa.

The white ants of Illinois all belong to the single species *Termes flavipes*, which ranges throughout the United States from the Atlantic to the Pacific, increasing in numbers southward to the Gulf and reaching a height of five thousand to seven thousand feet in the mountains of the West. In this State these ants are most frequently found in woodlands, burrowing in dead and fallen timber, but commonly having their principal place of abode in the earth. The lower rails of fences, stumps of trees, half rotten logs, and similar objects are frequently mined by them, many thousands of all forms living together and traveling back and forth in the extensive channels thus excavated. They have been found to infest and damage wooden bridges, dwellings, granaries, outhouses, and other buildings; fences, furniture, collections of books and papers, and rolls of cloth; roots of living trees, grape-vines, and shrubs; cotton plants, sugar-cane; and a variety of garden vegetables. Exposure to the light is evidently offensive and seemingly injurious to them, and they always work under cover, often burrowing extensively within the infested object and hollowing out its whole interior without giving any surface indication of their presence. Timbers thus infested sometimes collapse under pressure, endangering the safety of buildings, and floors and clapboards of houses are reduced to fragile shells through which the finger may be easily pushed. Where the course of their operations brings them into the light, they form covered passageways of mud or clay or of a kind of a paste or coarse *papier maché* made chiefly of the fiber of the wood through which they eat their way.

In April and May the winged male and female termites leave their secluded quarters and swarm abroad in myriads, often thus giving to the astonished householder his first intimation of their presence.

DESCRIPTION AND LIFE HISTORY.

Description of the Forms.—The common white ant or termite of the United States may be easily recognized by the nearly milk-white color of the greater number of individuals which compose a colony, by the fact of their living in large ant-like colonies, and by their general resemblance to our common ants, from which, however, they differ notably by the form of the abdomen, which is broadly joined to the thorax instead of being pedunculate.

If a white ants' nest be opened at any season of the year there will be found a large number of individuals about .16 inch in length, of a dirty white color, with heads of moderate size and small jaws. These are called the workers, for they perform all the various duties of the colony. They make the burrows, provide the food, and care for the young. They have no eyes, but the development of their instinctive powers is very remarkable. Although they have no power of reproduction, they may be looked upon as males and females whose sexual development has been checked while yet in the younger stages.

Associated with the workers, and resembling them in color, are representatives of the soldier caste, a little larger in size, with very large heads and strong jaws. They are bold and pugnacious in disposition, and upon them depends the protection of the colony. If their passageways are damaged, the workers retreat and the thick-headed soldiers appear in the breach, and with projecting wide-open jaws they move their heads threateningly from side to side, as if in search of an enemy. They are blind like the workers, and, like them, are undeveloped males and females.

Late in the spring or early in the summer winged individuals may be found in the nests. These are the sexually mature males and females, differing greatly in appearance from the workers and soldiers. They are black or dark chestnut in color, the body being about .2 inch in length, while the wings expand about .63 inch. The wings when not in use lie along the back, projecting more than half their length beyond the end of the body. Sometimes swarms of these creatures appear in May and June. After flying a greater or less distance they alight on the ground, and then shed their wings. The males seek the females at this time, but it is supposed that pairing does not take place till a later period. These swarming termites are ravenously devoured by birds and other insectivorous animals. According to Dr. Hagen*, a swarm of them in Cambridge, Mass., was followed by fifteen species of birds, some of which so gorged themselves that they could not close their beaks. After such a flight, females are taken in charge by the workers and new colonies are forned.

INJURIES IN ILLINOIS.

Twelve cases of notable injury by white ants in this State have come to my knowlege, and one was reported by Mr. B. D. Walsh, the first State Entomologist of Illinois. In three of these cases books and papers were damaged; in six, dwelling houses and other buildings; and in four the roots of cultivated trees. Fence posts and rail fences have been repeatedly found infested, and in one case a curious injury to bee hives found its explanation in the tunneling and burrowing of these insects.

The most serious instances of injury to libraries were reported from the old State House in Springfield in 1868 and from the new State House in 1892, books and public documents having been destroyed in both. (See frontispiece and Plate XII.) The dwelling houses damaged were near Granville, in Putnam county; at Varna, in Marshall county; at Dunlap, in Peoria county; near Tonti, in Marion county, and at Urbana, in Champaign county. The trees attacked were young pecans and apple nursery stock.

Injuries to Houses.—A remarkable case of injury to a small dwelling house, built on an open prairie in Putnam county, was brought to my attention by a letter from Mr. H. K. Smith, written April 19, 1886, in which he reported that some insect unknown to him was literally eating up a neighbor's house, granary, etc. Visiting this place, which was six miles west of Lostant, I found that the house (built twenty-one years before) consisted of a small main building resting on a brick foundation, and an additional lean-to, the floor-sills of which were laid upon the ground. About six feet from the house was a so-called cave, built in 1879 and lined with new lumber—pine and oak plank, the latter of which had been brought from a saw-mill about two miles away. Around the yard, passing a few feet from the house, was a post and board fence, and about thirty feet away was a granary with small out-houses near by.

The ants were first noticed in 1881, when they were seen to collect on the floor, under a jar which had been left there for several days. In 1884 the wooden walls of the "cave" broke in, and in 1886 it collapsed completely, all the lumber in it being practically destroyed. The fragments of this wood remaining contained a great number of white ants at the time of my visit. They were also found in several posts of the fence six or eight feet away, but had not visibly affected a young ash-tree about ten feet from the cave. The lean-to, on the other hand, was

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* Proc. Boston Soc. Nat. Hist., Vol. XX., p. 118.

thoroughly infested by them, the surface of the sills being generally gnawed or riddled to the depth of an inch or more. The clapboards, eaten in many places to a shell, were readily broken by the fingers, the ends of the boards especially being eaten and broken away. The window-casing above and below the window was almost completely hollowed out; even the shingles on the roof contained many ants; and the floor was also somewhat eaten. This damage extended across both ends of the lean-to, which was about ten feet wide, but did not reach the main part of the house.

Two years before, in 1884, the owner had taken a board from the cave to the granary, and in 1886 the floor of the oats bin had broken through, spilling the oats upon the ground. An examination of pieces of wood from this building showed that the ants had practically eaten up the floor, and that they had also gnawed away the surface of the wooden lining of the bin as high as the grain extended, sometimes to a depth of half an inch or more. In the woods near the saw-will whence the oak lumber for this farmer's "cave" originally came, I found an abundance of white ants in fallen rotten wood.

After my visit the owner destroyed his granary and thoroughly cleaned out the cave, burning up all the damaged wood, but neglected to follow my advice to kill all the ants on his premises with kerosene or gasoline. They were consequently still continuing their injuries to the house in 1888, and had also infested a corn-crib near by. About May 20 of that year they swarmed on two different days, many thousands of large brownish ants coming out of the walls of the house, indoors and out, and flying away. "Wherever they came out," writes Mr. Smith, "they passed between rows of soldier ants which stood with their heads just protruding from the cracks and holes of the walls.

An interesting case, similar to the above, was reported to me in June, 1890, by Mr. A. Harrison, of Dunlap, Peoria county. In this instance also the ants had thoroughly tunneled, weakened, and largely destroyed one side of a house, working upon the studding around the windows and doors and hollowing out the clapboards or outer covering of the wall. In this case experiments at destroying them with turpentine and kerosene were only partially successful, because of the difficulty of reaching them without tearing the house to pieces. The owner finally reported complete success with sulphur smoke, the sulphur being burned in a can with a spout through which the smoke could be driven into the infested wall. Injury to another house in the neighborhood was also reported at this time.

In Varna, Marshall county, the house of Mrs. E. B. Green had been infested for several years when the owner wrote me in 1888. At this time the wood-work of the windows had been honeycombed and the supports of a heavy chimney undermined.

White ants were also found by us in a house which belonged to Judge Vaughan, near Tonti, in Marion county, where they had come up through a carpet from the floor beneath and had hollowed out a book which lay upon the floor, eating out the greater part of its interior. About two feet from the corner of the house was the dead trunk of a large coniferous tree, covered with vines. It gave no external evidence of the presence of the insects, although it was completely honeycombed within, and white ants were abundant in it. The house had doubtless become infested from this tree.

Another dwelling near Tonti, that of Mr. A. Cope, was also found infested from the foundation to the eaves, many of the timbers, especially those of the porch of the dwelling, being badly eaten. Winged specimens had been noticed swarming from the walls of this house in April of three successive years. The timbers supporting the infested porch had been largely replaced because of the damage by the ants, the owner supposing that the wood had simply rotted away.

At Urbana, Illinois. the house of N. C. Ricker, Professor of Architecture in the University, was visibly infested by these insects for several years. Here they escaped in swarms, at the pairing season, from the upper parts of the house, and especially from under the eaves. They were apparently exterminated here, however, by pouring pure kerosene and gasoline into the holes from which they emerged and into their burrows in the ground at the base of the building.

A curious instance of injury came to my notice through a communication from Prof. J. B. Turner, of Jacksonville, Illinois. An assistant who visited his place found several wooden beehives entirely ruined by white ants. These hives were resting on wooden cross-pieces lying on the ground, and were protected by an open shed. The insects had evidently first entered the cross-pieces and gone from them into the bottom and sides of the hives, which they had reduced to hollow shells, filling the excavated portions with earth as they went. In some cases their covered galleries had been carried over the inner surface of the hive.

Injuries to Bridges.—I have found but a single reported instance of injury to a bridge; that described by Dr. Hagen, in 1876.* The fact that wooden bridges commonly occur in woodlands, and that their foundation timbers at least are always more or less moist, would lead one to expect occasional damage to such structures by white ants, and it is quite possible that such damage occurs, and that when detected the cause is overlooked. Considerable inquiry among railroad officials and agents of bridge companies has, however, led me to the conclusion that such damage must at least be rare, since I have learned no instance of it in Illinois.

Injuries to Books and Papers.—Concerning the first injury to State documents in this State, previously mentioned, I have no definite information except that contained in the following reference published in the "American Naturalist,"* by Dr. H. A. Hagen, of Harvard University:

* Am. Naturalist, Vol. 10, p. 406.

"Two years later [1868] I was presented by the late B. Walsh, in Rock Island, with a copy of the State papers of Illinois which were destroyed by the white ants. All the spare copies were stored in a closed room, and not looked after for some time; when the room was opened all were found in the same condition. I can never look upon the volume without being puzzled by the remarkable fact that the queer little rogues failed to attack the name of Vandalia on the top of the pages."

This incident has some special interest as affording a plausible explanation of the origin of a better known outbreak of these insects in the basement of the present State House at Springfield, which came to my knowledge in 1892. From a book given to me at that time, taken from the storage room of the Department of State, the plate was made which appears as a frontispiece to this Report.

My attention was first called to the difficulty by a letter from Capt. John M. Adair, Assistant Secretary of State, written July 15, 1892. "I discovered to-day," he says, "a colony of white ants—so they say they are—in some papers in the basement of the State House. I send you a sample of their kind and of their work. I want you to tell me what I shall do to destroy them, and whether they are liable to spread to other parts of the building. * * * If the papers should be removed from the room in which they are I want to do this. I do not know how they were introduced. Does the insect thrive in dry places or only in damp? These papers are somewhat damp by coming in contact with the wall."

After a cursory examination of the situation there in September, I sent an assistant, Mr. John Marten, to Springfield October 5 and again November 10 to investigate the matter. From Mr. Marten's written report, on file in my office, the following account is condensed.

White ants were found abundantly infesting collections of papers and books stored on wooden shelves in four adjoining rooms in the basement of the east wing of the State House, and also in a fifth room, separated from the fourth by a hall. In the first room visited—that in the extreme southeast corner of this wing—white ants were found in papers stored in open tin boxes which had been fitted loosely into pigeonholes, one box for each hole. These cases had been made about five years before of new pine and poplar (*Liriodendron tulipifera*). The bottom board of each rested upon the cement floor, and the backs and ends of the shelving frequently touched the stone and brick walls. The ants had evidently made their way into the cases at these points of contact, and the top and bottom boards were worst eaten out. The ends of the shelves were generally honeycombed, and on the surfaces of the boards covered ways had frequently been built, where the burrows of the insects came to the light. The part of the case worst injured was that resting on the floor, where the wood was a trifle moist. Here the shelving could easily be crumbled between the fingers. (See Plate XIII, Fig. 2.)

The walls exposed by the removal of the cases in this room presented an interesting appearance. Along the angle formed by the floor and the west partition wall ran a covered way which occasionally sent branches up the wall on to the bricks. Two of these branches led to smooth oval holes in the mortar between the bricks. Similar covered ways were found on the opposite side of this wall in the adjoining room, leading from holes in the mortar precisely like those just mentioned. There could be little doubt that the ants had tunneled through the solid brick partition wall, which was here three feet thick. Similar covered galleries terminating in passageways through brick partition walls were found connecting all the infested rooms except the fifth above mentioned, which was separated from the others by a wide corridor. (See Plate XIII, Fig. 2.)

Another covered way in the first, or southeast, room ran up the base of the outer stone foundation wall for a distance of about ten feet, and not less than four openings were detected in the mortar between the stones. Ants were seen passing into these openings, the largest of which was a little more than one eighth of an inch in diameter and nearly circular in section. The others were narrow-oval, one sixteenth by three sixteenths of an inch in diameter. These orifices were worn smooth, and evidently were not accidental.

Next, on the outside of this foundation wall, and consequently quite outside the building, a similar covered way was found upon the stones nearly opposite the interior one above described, and from this outer passage also tunnels extended into the wall, through which white ants were seen passing to and fro in great excitement. As no other ants could be found outside—although the entire circumference of the foundation of the State House was closely searched—it seems quite probable that these outer and inner works communicated with each other through the stone wall itself, which was at this place not less than six feet thick. Indeed, the shape of the wall was such that the ants must have burrowed at least eight feet through the mortar between the stones in order to make this passageway. It is difficult to see what could have been the motive of the ants for burrowing into and through the massive walls of the foundations of the State House while they still had within the rooms occupied by them suitable quarters and abundant food. The fact that burrows in the foundation wall and in the brick partitions were occasionally found which did not open on the other side makes it seem likely that these insects have a persistent tunneling instinct which leads them to carry their hidden explorations in every direction without reference to immediate benefits, and that they were in this way led, step by step, to bore their way through the foundation wall of the building with the final effect to give them access to outdoor situations and sources of food supply.

Similar examples of persistent and extensive tunneling operations and long covered passageways were found in all the infested rooms, and in all of them the shelves and bookcases had been burrowed and hollowed out, while the books and papers contained were more or less damaged by the ants. There was thus a complicated and continuous system of covered galleries and of tunnels through stone, brick, and wood leading from the earth outside the State House into and through a series of four basement rooms. The mode of access to the fifth, isolated room was not discovered.

In one of these rooms some old cases of poplar shelves made at the old State House sixteen years before had been stored for many years. These cases were very badly burrowed, the bottom boards especially being reduced to shells and breaking in two when lifted; and it seems possible that the ants were brought into these rooms originally in these old bookcases.

It was evident in all these rooms that it was the woodwork of the cases that attracted the white ants primarily, injuries to books and papers being wholly secondary. Further, damage to both wood and paper, while not confined to moist materials, was very much more general and thorough in them than in dry objects. One very badly infested storage case in the southeast room of the basement, the first of the series above mentioned, contained papers none of which were infested, although the bottom of the case was completely honeycombed and supported in some places only by masses of clay which the ants had substituted for the devoured wood. This clay was itself tunneled and chambered in every direction. Pieces of 2x4 pine used as supports under the shelves were burrowed from end to end and through and through, and in fact the whole structure next the floor was little more than a mass of rubbish.

The nature of the injuries to books contained in infested cases is well illustrated by the frontispiece to this Report. At the lettered points on this plate burrows extend directly into the book, at *a* and *h* through the entire volume (528 pages). Sometimes such channels run from book to book, perforating several volumes in succession. Stored boxes of paper were found in one of the rooms, which had not been moved for about two years. The boards under these boxes had been completely honeycombed, and the ants had burrowed upward some inches into the mass of paper itself.

In the various chambers and runways exposed by these investigations, quantities of ants were found at the time of Mr. Marten's visit, the greater part of them wingless workers, a few of them soldiers, and a few young larvæ. A small number of so-called pupæ—that is young of the sexual forms whose wings are not yet grown, but are represented by wing-pads—were mingled with the crowd, but no fully developed males and females and no eggs were seen.

The only remedy found necessary in this case was a thorough cleaning out of the rooms, the burning or heating of the infested objects, and the removal of the books and papers to cases so built and placed that they did not come in contact with the wall and touched the cement floor only at a few points of support. In this way the gradual moistening of masses of wood was avoided, and the ants seem now to have completely disappeared from these basement rooms.

Injuries to Vegetation.—Three cases of injuries to apple roots were reported to me in August, 1891, from Carbondale, by Mr. G. H. French, of the Southern Illinois Normal School. Two of these trees had recently died, and it was not certain that they had been infested by the ants while still alive; but the third tree was still living, although not vigorous.

As far back as 1884 I received from Mr. Benjamin Buckman, of Farmingdale, Sangamon county, Ill., some pieces of the wood of a cultivated pecan tree, taken from below the surface of the ground, which were thoroughly honeycombed by termites. My correspondent reported that he had several trees killed in this manner, the tree appearing sound on the surface, but breaking off in the wind.

Miscellaneous Notes.—An instance of the association of these termites with a common species of red ant (*Formica schaufussi*) was reported by Mr. Marten, May, 1887. On turning over a log on the ground, near Carterville, in Mason county, he disturbed a nest of these red ants, and found also termites abundant in the log. The ants at once began carrying off the latter in great numbers, picking them up alive and hurrying them into their subterranean burrows as they do.

Among a lot of white ants collected at the State House, in Springfield, October 9, 1892, and kept in my insectary until February of the following year, an outbreak of "gray muscardine" occurred, characterized by the parasitic fungus *Entomophthora aphidis*. This attack killed a considerable number of the colony, but not all. These ants burrowed freely in buried wood provided them for the purpose, making tunnels with external openings similar to those above described.

In another lot, brought in from the woods at White Heath, Piatt county, October 18, 1892, and kept in the insectary under conditions favorable to their maintenance, an outbreak of another parasite appeared—the common fungus of white muscardine, *Sporotrichum globuliferum*. This was probably the result of an accidental infection in the insectary itself, as chinch-bug experiments with this fungas were in progress there at the time.

PREVENTION AND REMEDY.

Buildings are not liable to injury by white ants if they rest throughout on brick or stone foundations unless door frames or window frames in foundation or basement stories are exposed continuously to moisture. As the ants prefer moist wood, they seem never to establish themselves in buildings where the woodwork is usually dry throughout. Where timbers are set in the ground they may doubtless be protected by the treatment usual as a preventive of decay, especially if any of the creosote preparations or other tarry substances are used for this purpose.

Libraries and store-rooms for books and papers are also little likely to become infested if everything about them is kept perfectly dry. Bookcases in basement rooms should not be allowed to touch the wall, and should be lifted from the floor on short legs or small block supports. If the points of contact with the floor could be made of metal, this would secure complete immunity. In transferring stored records and books in old cases from one building to another, the woodwork and the contents of the cases should be inspected, as a little carelessness at this point may result in the introduction of library pests capable of doing enormous damage, especially in large public collections, before their presence is detected. These pests are readily killed by fumigation by methods presently to be described.

Injuries to vegetation by white ants are so rare that methods of prevention need hardly be discussed.

When buildings are so slightly infested that the damage already done is insignificant, it can be arrested by destroying the ants themselves by the use of fluids or vapors fatal to them. Gasoline is perhaps the most convenient and serviceable of these, although of course it must be used with caution, and sometimes cannot be applied thoroughly enough to effect the purpose. Kerosene or benzine may be used instead of gasoline. Carbon bisulphide will sometimes be found practically useful, especially as it is a highly volatile fluid, and the vapor into which it is rapidly converted is itself deadly to the ants. As this vapor is heavier than air, this fluid should be poured on or into infested structures at the highest point. This also must be used with caution, as it is both a poisonous and explosive substance. The fumes of burning sulphur, chlorine gas, and nitrous-acid gas are all fatal to these pests. For ordinary use the first will be found the most convenient, as the sulphur may be burned in a closed vessel with a spout through which the gases of combustion can be thoroughly introduced.

If plants become infested, applications of hot water or of kerosene emulsion will commonly be found the most convenient. They must be very freely used to saturate the infested tissues and to kill the ants in their burrows around about. Indeed in all cases a thoroughgoing search of the whole vicinity is necessary, to be followed up by a free application of suitable insecticides wherever traces of the insects appear.

DESCRIPTIVE LIST OF ECONOMIC ARTICLES CONSULTED.

1837.

Kollar, V.—Naturgeschichte der schädlichen Insekten, p. 411.

Contains description of *Termes flavipes* and refers to injuries in hothouses at Schönbrunn and Vienna. Contains original description of *Termes flavipes* and an account of injury in 1837 to hothouses in Schönbrunn belonging to the Emperor of Austria.

One of these buildings was so badly damaged that it was found necessary to tear it down to prevent its collapse. Insects believed to have been imported with plants from America.

Haldemann, S. S.—Proc. Acad. Nat. Sci. Phil., 1844, v. 2, p. 55.

Under the caption, "Descriptions of Insects presumed to be undescribed," occurs a description of *Termes frontalis*, which is identical with *Termes flavipes*. Found by Haldemann in and under logs.

1856.

Fitch, Asa.—Third Rep. State Ent. N. Y., 1856, p. 151 (sec. 196).

Gives a brief description of *T. frontalis* (=*flavipes*), found in decaying stumps and logs lying on the ground.

1858.

Fitch, Asa.—Fourth Rep. State Ent. N. Y., 1858, p. 8.

Reports destruction to chestnut posts and rails by *T. frontalis* (=*flavipes*), and states that it burrows in white pine (*P. strobus*) more than in any other tree. Has observed that "it sometimes lives in society with and is nursed and protected by the common black and red ant (*Formica rufa*).

1860.

Scudder, S. H.—Proc. Boston Nat. Hist. Soc., v. 7, p. 287.

Reports case of fatal injury to roots of grape-vines in forcing houses at Salem, Mass., which he believes to be the first proven instances of destruction to living vegetable matter by the white ant. The excavations of the ants were carried into solid living wood, and pushed an inch or more above the surface of the ground.

1862.

Buckley, S. B.—Proc. Ent. Soc. Phil., v. 1, p. 215.

Says that *Termes flavipes* is the most abundant species of the genus found in Texas.

1870.

Riley, C. V.—Second Rep. State Ent. Mo., p. 11; Ninth Rep. State Ent. Mo., p. 43.

Brief reference to injuries done in Germany by *T. flavipes*.

1876.

Hagen, H. A.—Am. Nat., v. 10, p. 62.

At a meeting of the Cambridge Entomological Club (Nov. 12, 1875) Dr. Hagen exhibited female white ants (*Termes flavipes*) from Florida—the so-called queens. Says these are the first queens of this species ever found in this country.* Are wingless, but sexually mature. Speaks of damage to wooden buildings where white ants are present.

HAGEN, H. A.—Am. Nat., v. 10, p. 406.

An interesting and valuable paper on "The Probable Dangers from White Ants." Reports injury to sills of a house in Salem, Mass., that of the fence round the Observatory at Cambridge, and that of a wooden bridge in the same town. This bridge gave way suddenly, when a herd of cattle were running across it. The timbers had been tunneled so extensively by white ants that it was necessary to rebuild the bridge. Timbers supporting the ceiling of a workshop of Alvan Clark and Son, instrument makers at Cambridge, Mass., so badly damaged by white ants that they gave way in 1876. Notes injury to State papers in Illinois in 1868 by white ants.

1877.

GRANT, R. D.—Trans. Acad. Sci. St. Louis, v. 3, p. cclxix.

Reports insect injury to wood and masonry of an engine-house belonging to the Missouri Pacific R. R. Co. Rafters injured to such extent that roof had to be removed; and cement of brick walls perforated in all directions. Dr. Riley identifies the insect as *Termes flavipes.*

HAGEN, H. A.—Proc. Boston Soc. Nat. Hist., v. 19, p. 73.

Remarks that among a lot of termites collected in California by Baron Osten-Saken, the species from Sonoma county was not distinguishable from *Termes flavipes* of the United States.

LIEDY, JOSEPH.—Proc. Phil. Acad. Nat. Sci., 1877, p. 146; Abstract, Am. Month. Micr. Journ., v. 2 (1881), p. 95.

A descriptive and biological article on "Intestinal Parasites of *Termes flavipes.*

1878.

HAGEN, H. A.—Proc. Soc. Nat. Hist., v. 20, p. 118.

Note on the flight of *Termes flavipes* (May 19). Followed by fifteen species of birds, which caught them partly in flight and partly on the ground.

1879.

MCCOOK, H. C.—Proc. Phil. Acad. Nat. Sci., 1879, p. 154.

In a "Note on Mound-making Ants" states that *Termes flavipes*, found under stones in the neighborhood of the Alleghanies were instantly seized and carried off by the mound-builders (*Formica exsectöides*) when disturbed.

* It is now regarded as doubtful if true queens of *Termes flavipes* occur.

1880.

COMSTOCK, J. H.—Rep. U. S. Dept. Agr., 1879, p. 207.

T. flavipes found attacking living pampas grass, orange-trees, guava bushes, and sugar-cane in Florida. Damage chiefly confined to that part of plant just below the surface of ground. Remedial measures suggested.

HAGEN, H. A.—Rep. Ent. Soc. Ont., 1879, p. 31.

Says that *Termes flavipes* was probably introduced into Europe from this country.

[RILEY, C. V.]—Am. Ent., v. 1, n. s., p. 15.

Trichopsenius depressus and three other rove-beetles (Aleocharina) found living in galleries of *Termes flavipes* in Texas by E. A. Schwarz.

1883.

HUBBARD, H. G.—U. S. Dept. Agr., Div. Ent., Bull. 1, p. 36.

Says that *Termes flavipes* does great damage at surface, girdling orange-, lemon-, and lime-trees. Also eats tubers of artichoke.

HAGEN, H. A.—Boston Transcript, Nov. 15, 1883.

Account given reporter concerning white-ant ravages in the State House, Boston, Mass. Other injuries to buildings and to bridges mentioned.

"BUILDING."—(New York), Dec. 1883, p. 34.

States that the Governor ordered inspection of the State House on the strength of Dr. Hagen's "Transcript" article above cited, and found that the white ants had made extensive excavations beneath the foundations of the building, causing grave and imminent danger. Had also nearly destroyed taxation papers for twenty years, stored in the so-called dungeon of the State House.

PACKARD, A. S.—Third Rep. U. S. Ent. Comm., p. 326.

In a paper treating of the systematic position of the Orthoptera in relation to other orders of insects *Termopsis angusticollis* and *Termes flavipes* are figured and compared.

1885.

HAGEN, H. A.—Can. Ent., v. 17, p. 134; Sixteenth Rep. Ent. Soc. Ont., p. 16; Fifth Rep. U. S. Ent. Comm. (1890), p. 387.

Living maple-trees (*Acer rubrum*) destroyed by *Termes flavipes*, in Cambridge, Mass., and earth in hothouses infested by white ants.

HAGEN, H. A.—Can. Ent., v. 18, p. 221; Seventeenth Rep. Ent. Soc. Ont., p. 46.

Refers to *Termes flavipes* as a library insect, in an article, under the title of "A New Library Pest," which deals with *Lepisma domestica*.

1888.

COMSTOCK, J. H.—Introduction to Entomology, p. 77.

An excellent illustrated account of the termites, with figures of *Termes flavipes* and *T. gilvus* (queen), containing biological, economic, and systematic notes.

KENT, G. H.—"Insect Life," v. 1, p. 17.

Under heading "Notes from Mississippi" states that he found *Termes flavipes* destroying cotton-stalks.

RILEY & HOWARD.—"Insect Life," v. 1, p. 341.

Reply to a foreign correspondent whose fruit-trees and vines are being killed by white ants, with mention of preventive and remedial measures for combating *Termes flavipes*, and some account of its characteristic injuries.

1889.

ATKINSON, G. H.—S. C. Exper. Station Bull. No. 4 (n. s.), p. 84.

Says that long stretches of board fences on the outskirts of Columbia, S. C., were damaged by *Termes flavipes*.

1890.

FISCHER, E. R.—"Insect Life," v. 2, p. 253.

Reports in a letter from St. Louis that white ants (identified as *Termes flavipes*) bored through paper and then through a bolt of Conestoga ticking into the shelf on which it had been lying for about one month.

KENT, G. H.—"Insect Life," v. 2, p. 283.

Has noticed *Termes flavipes* destroying collard-stalks and roots of turnip by gradually eating out the interior.

PACKARD, A. S.—Fifth Rep. U. S. Ent. Comm., pp. 283 and 354.

Termes flavipes observed injuring a "wounded elm-tree at Salem, Mass., and mention made of its mining the interior of chestnut posts and stakes, decaying trees, and sills of houses.

1893.

JOUTEL, L. H.—Journ. N. Y. Soc., v. 1, p. 89.

Notes on injuries by white ants to several houses in the City of New York.

Riley & Howard.—"Insect Life," v. 5, p. 201.

Receiving from New Mexico sections of an apple-tree showing injury by white ants ("probably *Termes flavipes*"), precautions and remedies are suggested to correspondent.

Stokes, A. C.—"Science," Nov. 17, 1893, v. 22, p. 273.

An important illustrated article on "The Sense Organs on the Legs of our White Ants (*Termes flavipes,* Koll)."

1894.

Kellicott, D. S.—Ent. News, Dec., 1894, v. 5, p. 314.

Notes of injuries to timbers by white ants (*Termes flavipes*) in the Electrical Building at the Ohio State University, Columbus, Ohio. Heavy posts and timbers supporting machinery were riddled by these insects and began to give way. Rested upon "cement below an asphalt floor," and had been in place about four years. Although white ants were found abundant in rubbish not far away, it was thought probable that those infesting these timbers had been brought into the building with the wood.

Smith, J. B.—Rep. N. J. Exper. Station, 1892, p. 494.

Has found white ants in roots of blackberries which had been attacked by borers and were beginning to decay. Although they sometimes attack living plants, generally speaking, they "are important factors in nature's routine, reducing to dust fallen trees and stumps." Figures the different forms of *Termes flavipes.*

EXPLANATION OF PLATES.

FRONTISPIECE.

Injury by White Ants to book in basement store-room at State House.

PLATE I.

Farm of G. C. Wells, near Farina, Fayette county; site of Experiments Nos. 55–58.

PLATE II.

Portion of University Agricultural Experiment Station Farm, at Urbana, Illinois, showing the site of Experiments Nos. 81–86.

PLATE III.

Farm of G. W. Heth, near Edgewood, Effingham county; site of Experiment No. 77.

PLATE IV.

Farms of Silas Hurd and Frank H. Robinson, near Odin, Marion county; site of Experiment No. 75, and of muscardine outbreak, No. 76.

PLATE V.

Fig. 1. Mason fruit-jar with altered cap.
Fig. 2. Chinch-bug imbedded in Sporotrichum bearing heads of ripe spores.
Fig. 3. A fragment of Sporotrichum from chinch-bug, spread out to show structure. Highly magnified.

PLATE VI.

Culture mass of corn-meal batter from fruit-jar, covered with Sporotrichum, showing its mode of growth on solid media.

PLATE VII.

ISARIA FORMS OF *Sportrichum globuliferum*, SPEG.

Fig. 1 and 2. On buried pupæ of the Apple Leaf Skeletonizer (*Canarsia hammondi*, Riley) as it appeared on the surface of the ground.

Fig. 3. On pupa of same, the fungus bursting through the cocoon.

Fig. 4. On buried pupa of same, uncovered and showing the fungus growth as it appeared below the surface.

Fig. 5 and 6. On June beetles (Lachnosterna) found in ground.

Fig. 7. On pupa of Walnut Caterpillar (Datana). From laboratory infection experiment.

Fig. 8. From White Grub dead under ground in breeding-cage From laboratory infection. The fungus immature and the spores not yet fully formed.

Fig. 9. The same as Fig. 8, but in a later stage, the fungus being mature, and the spores ripe.

PLATE VIII.

Circular copper pan used in making sterile cultures.

PLATE IX.

Growth of *Sporotrichum globuliferum* on corn-meal and beef broth in culture pan.

PLATE X.

Map of Illinois, showing area and extent of distribution of muscardine fungus in 1894. The figures for each county indicate the number of townships to which such infection material was distributed in June and July.

PLATE XI.

Breeding-cage for confinement of Chinch-bugs, *Blissus leucopterus*, egg experiment.

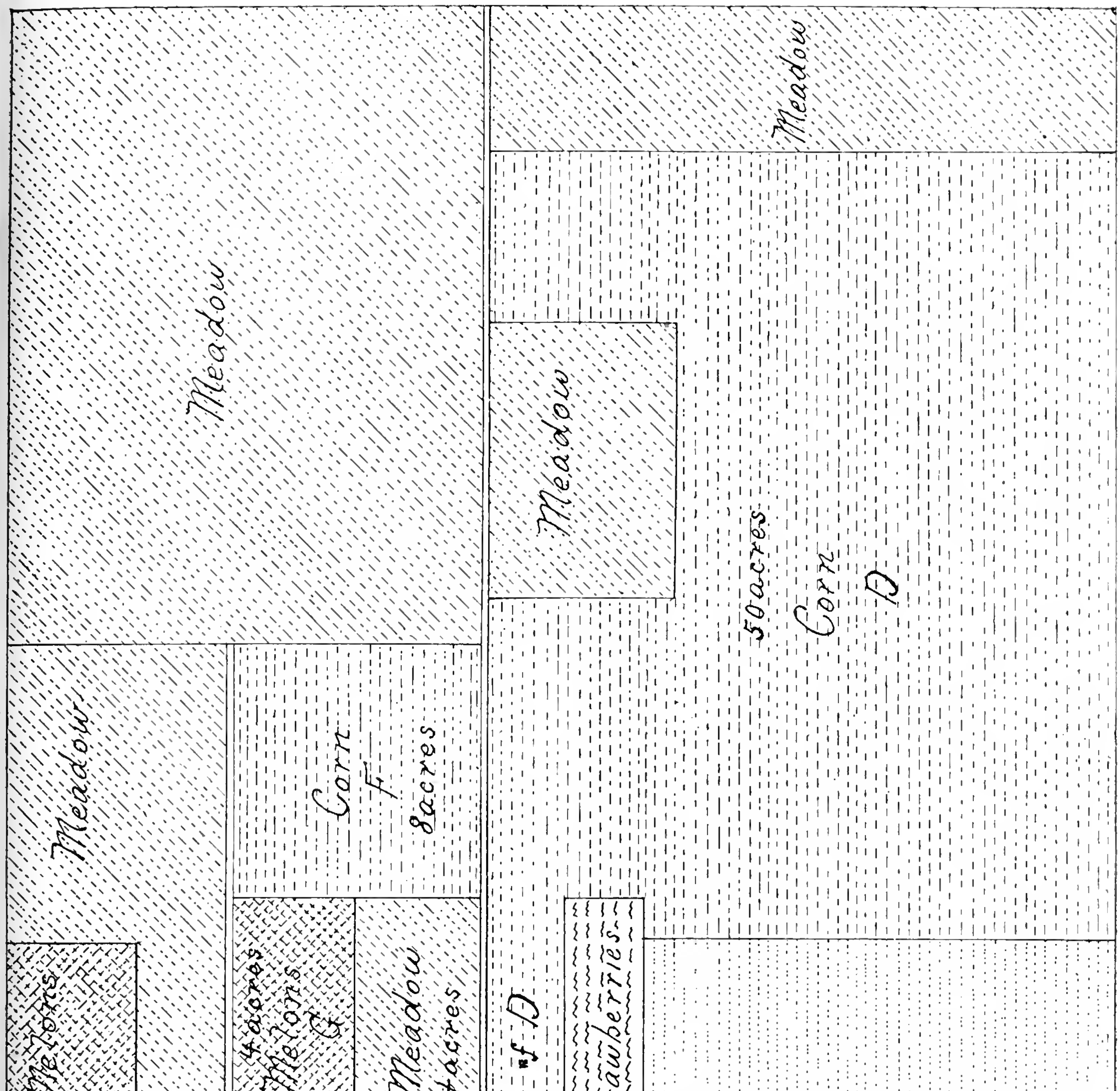
PLATE XII.

Document from State House (House bill) showing work of White Ants, *Termes flavipes*.

PLATE XIII.

Work of White Ants, *Termes flavipes*: 1. Piece of cement from State House showing tunnels; 2. Piece of shelving from basement store-room at State House, with outer surface removed, showing burrows.

PLATE I.



Meadow
Meadow
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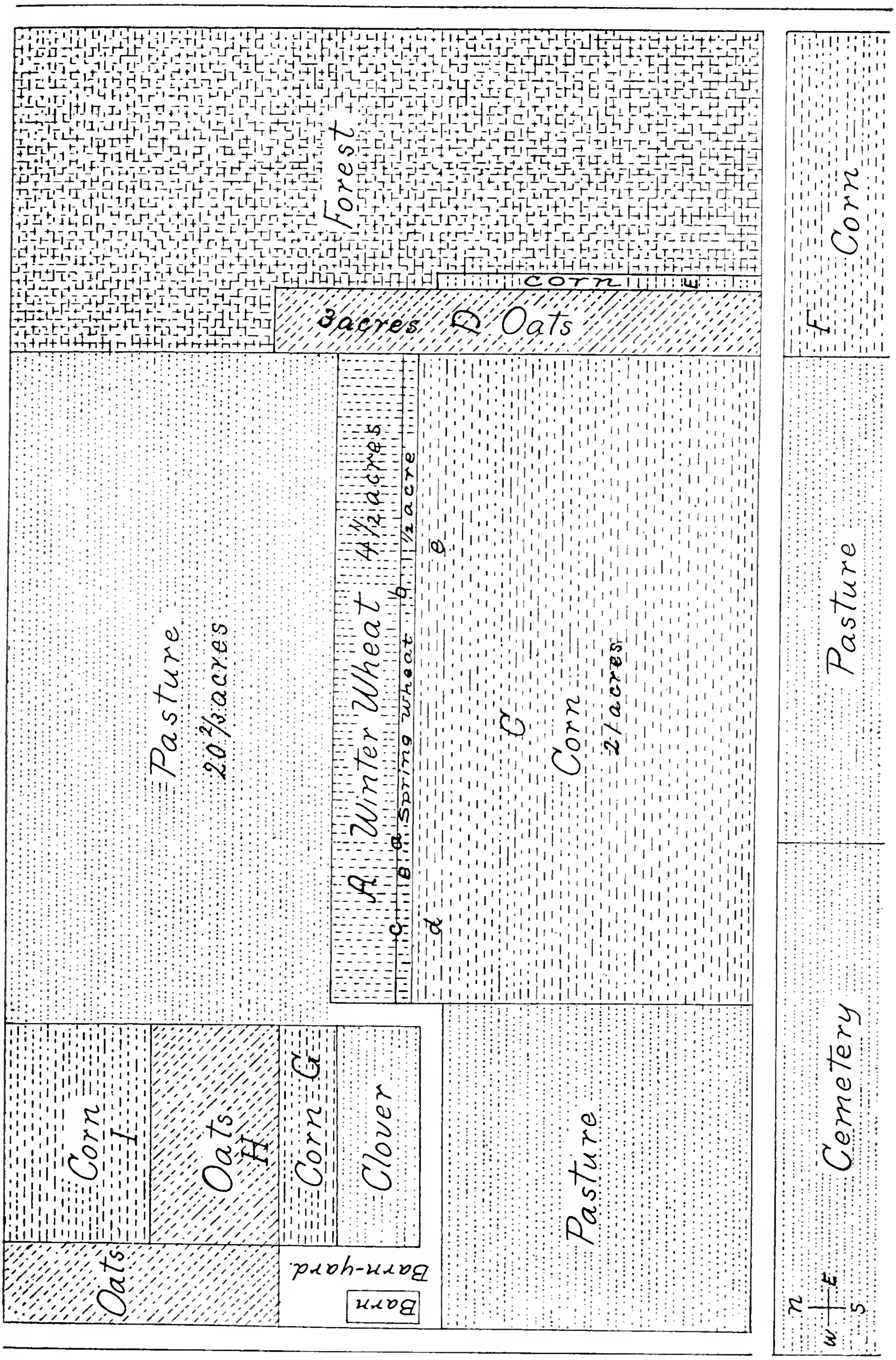
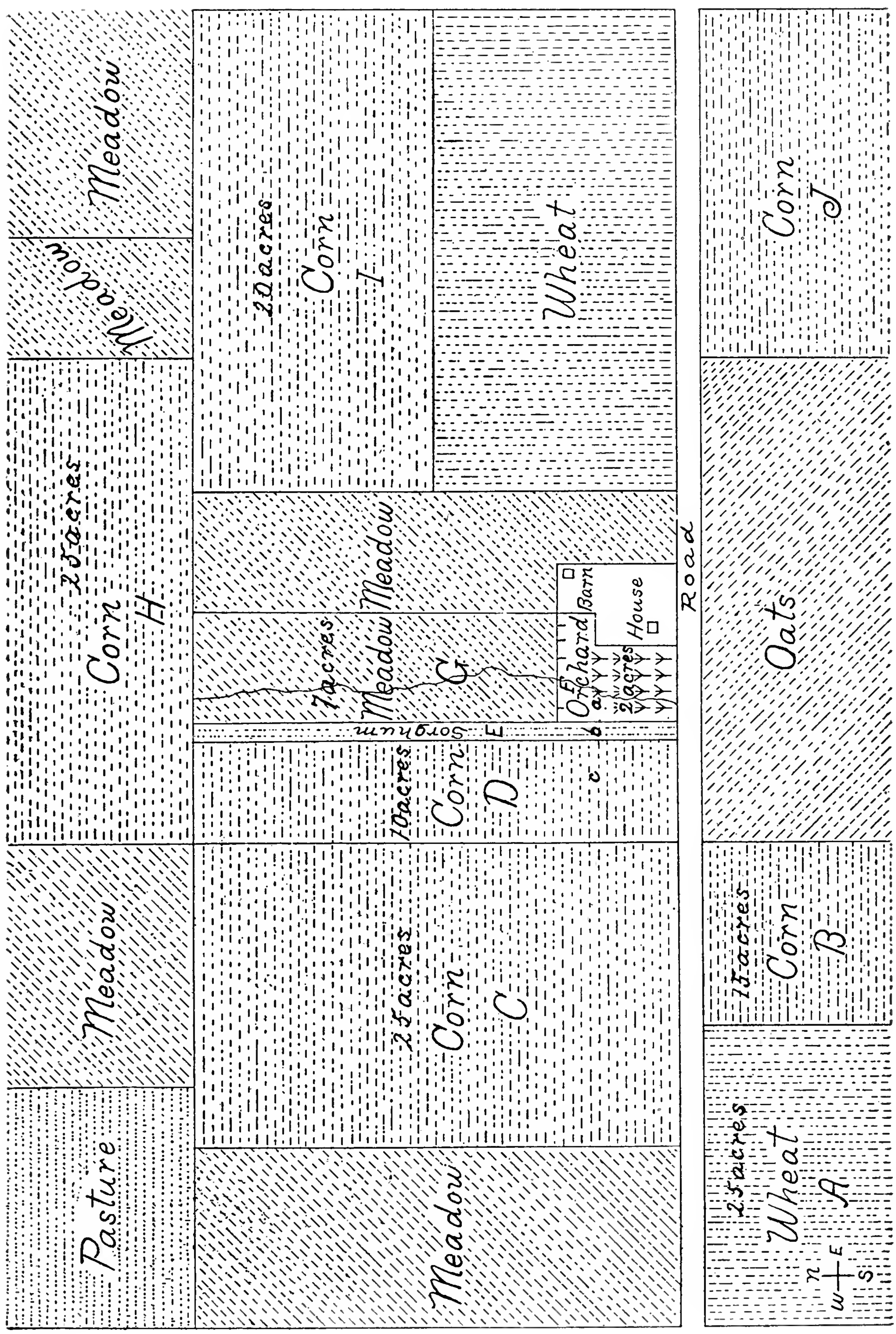
Corn
D
50acres
Corn
F
8acres
Melons
4acres
Melons
G
Meadow
4acres
f D
Strawberries
Oats
C
Orchard
5acres
Corn
B
12 acres
E
House.
4½acres
Wheat
A
Pasture
50acres
N
E
S
W
Road

PLATE II.



Forest
CORN
E
3acres D Oats
F Corn
Pasture
20 2/3 acres
A Winter Wheat 4½ acres
c B a Spring wheat b ½ acre
d e
C
Corn
21 acres
Pasture
Corn I
Oats H
Corn G
Clover
Pasture
Cemetery
Oats
Barn-yard
Barn
n E w S

PLATE III.



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Meadow
Pasture
20 acres
Corn
I
Wheat
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7 acres
Meadow
G
Sorghum
E
10 acres
Corn
D
25 acres
Corn
C
Meadow
Orchard
F
2 acres
Barn
House
Road
Corn
J
Oats
15 acres
Corn
B
25 acres
Wheat
A
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E
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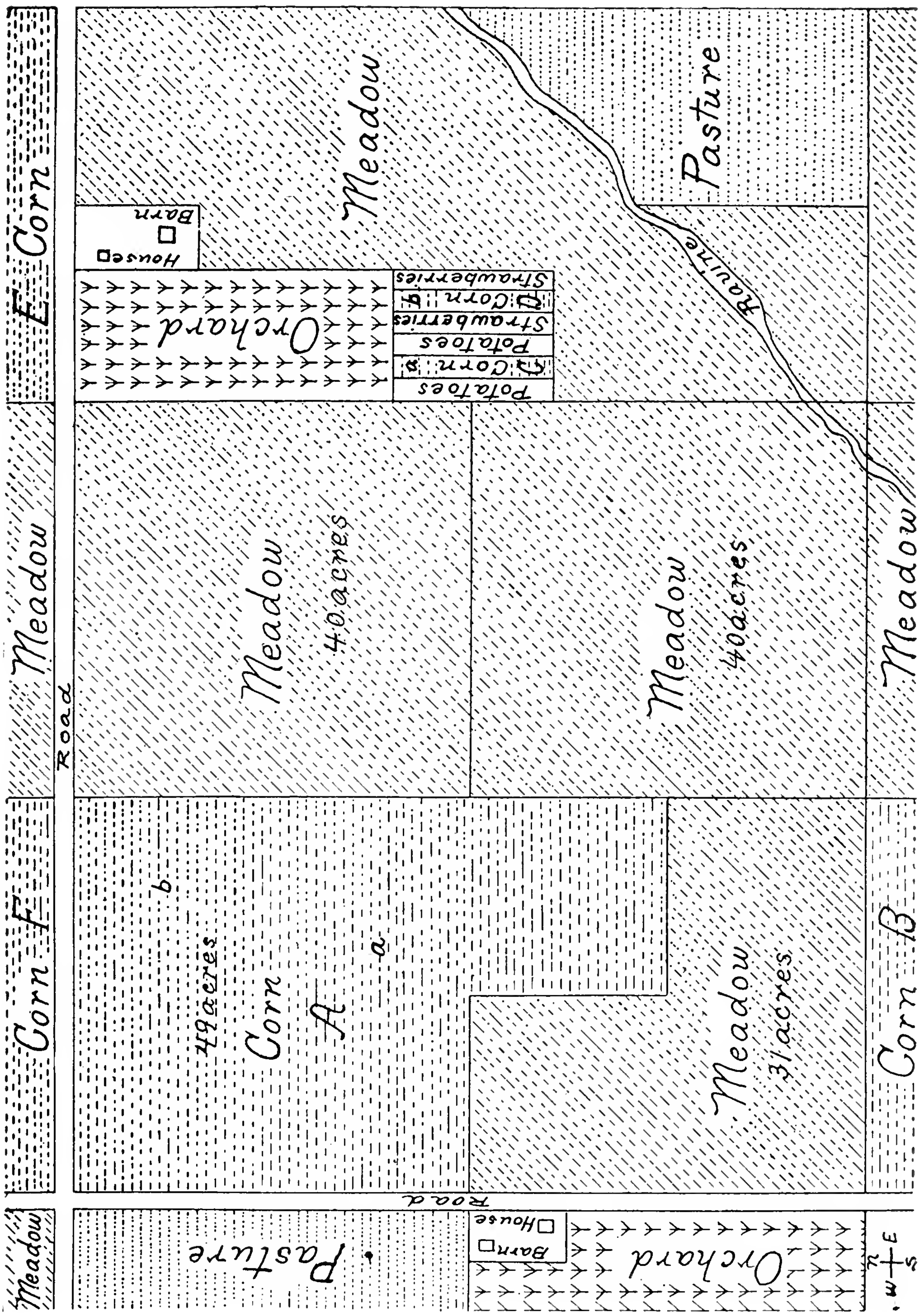
PLATE IV.



Meadow
E Corn
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House
Barn
Orchard
Strawberries
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Potatoes
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Ravine
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PLATE V.

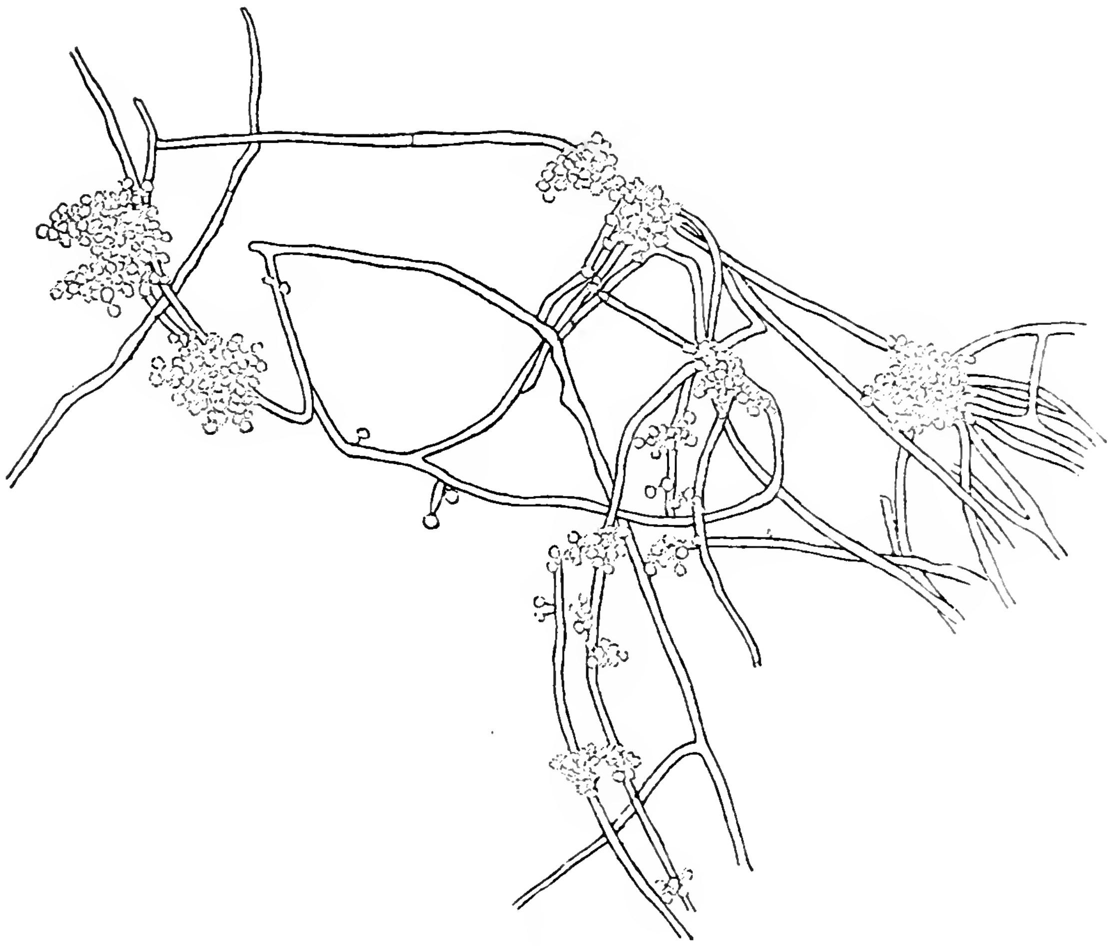

Fig. 3.

Fig. 1.

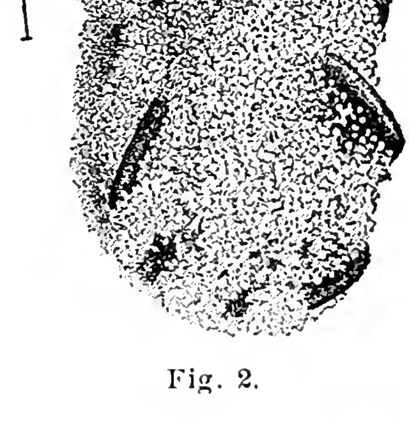

Fig. 2.

PLATE VI.

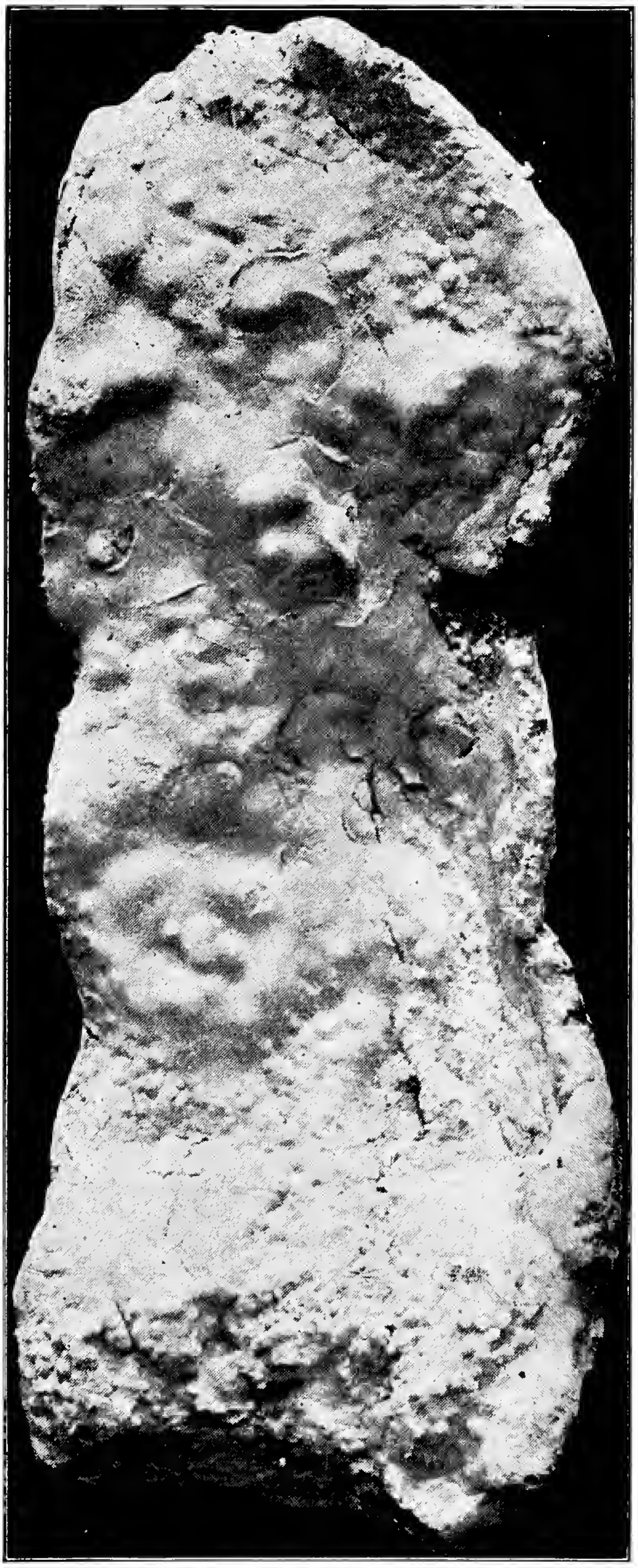

PLATE VII.

Fig. 7.

Fig. 1–4.

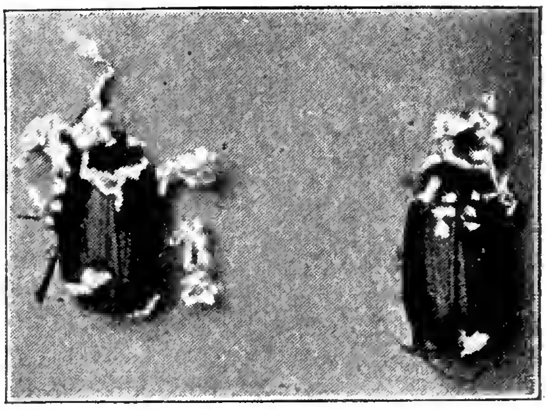

Fig. 5, 6.

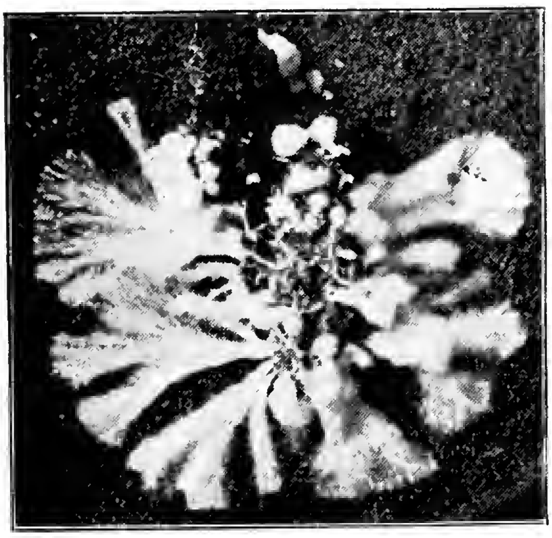

Fig. 8.

Fig. 9.

PLATE VIII.

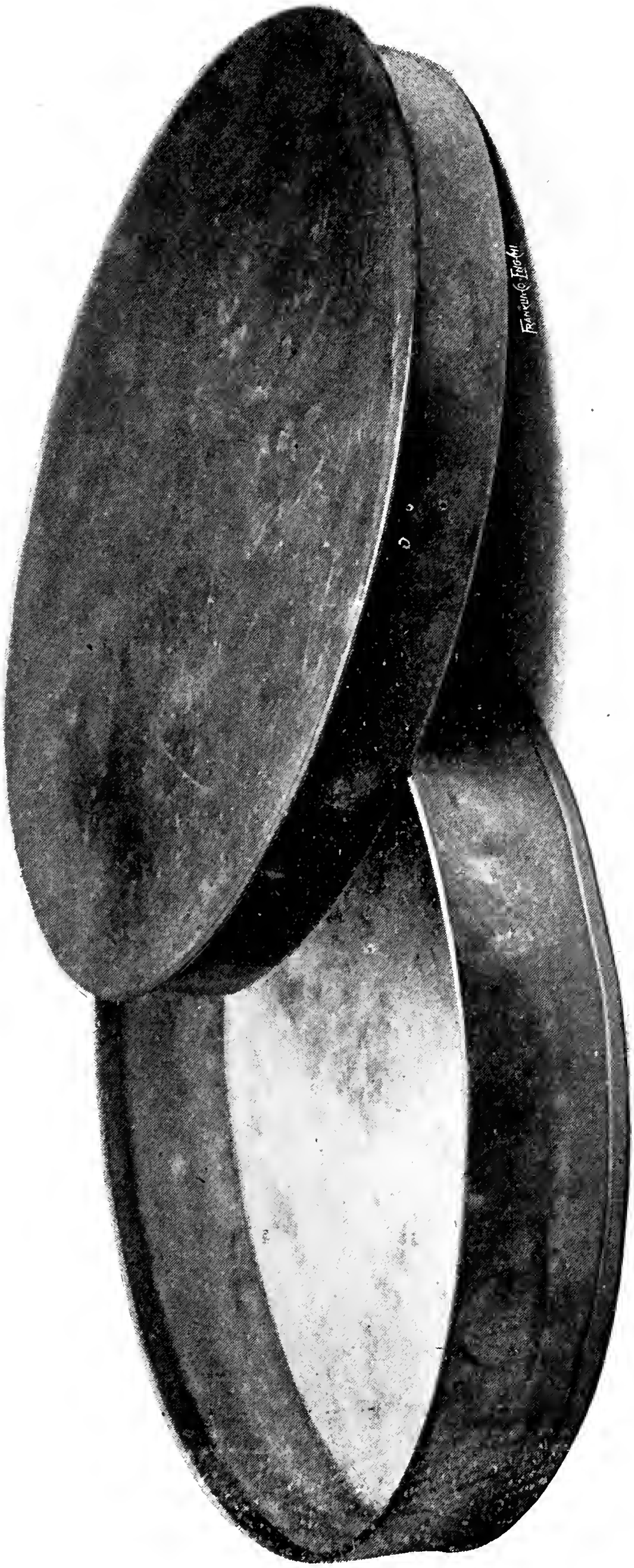

PLATE IX.

Plate X.

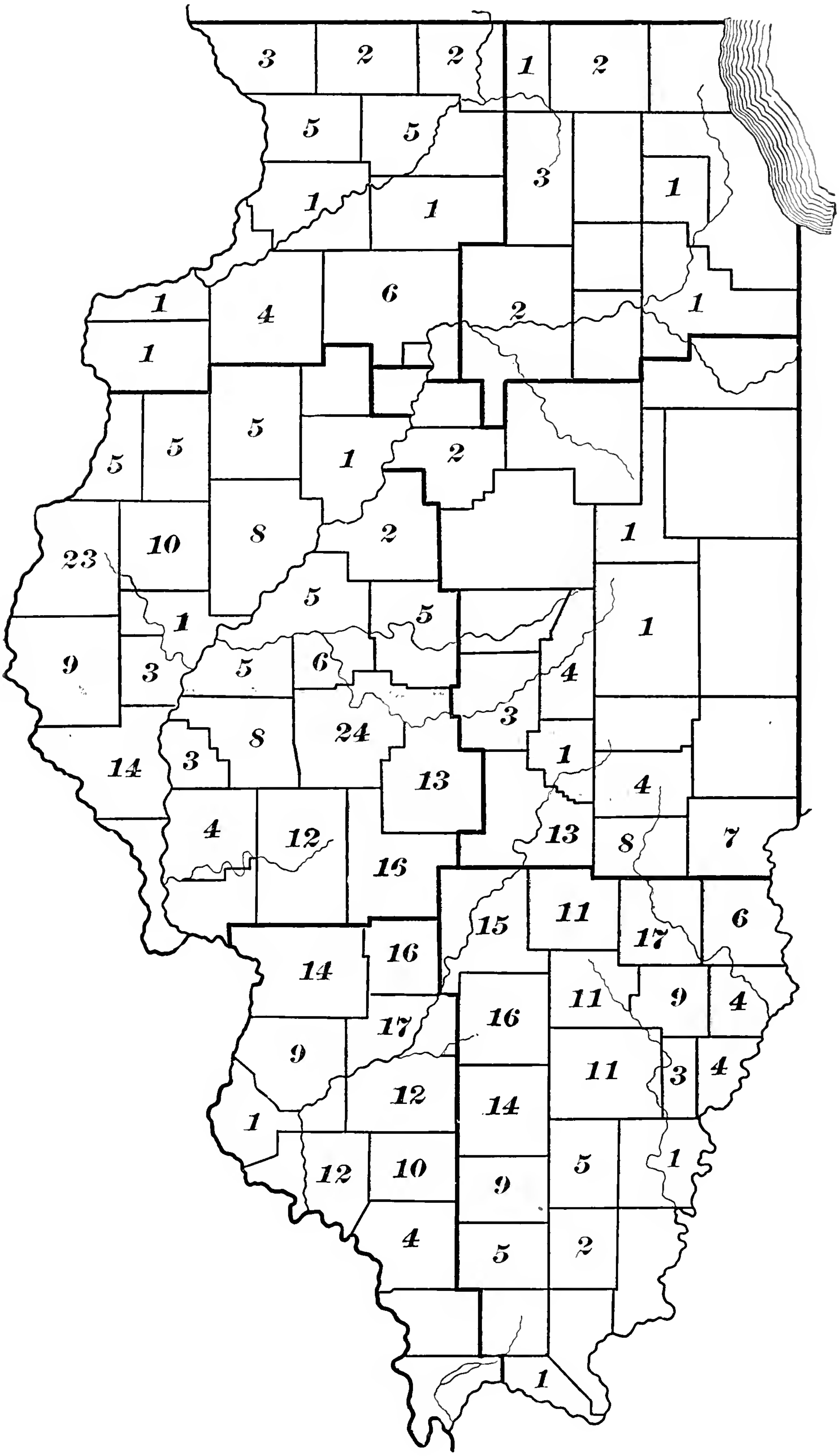

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Plate XI.

PLATE XII.

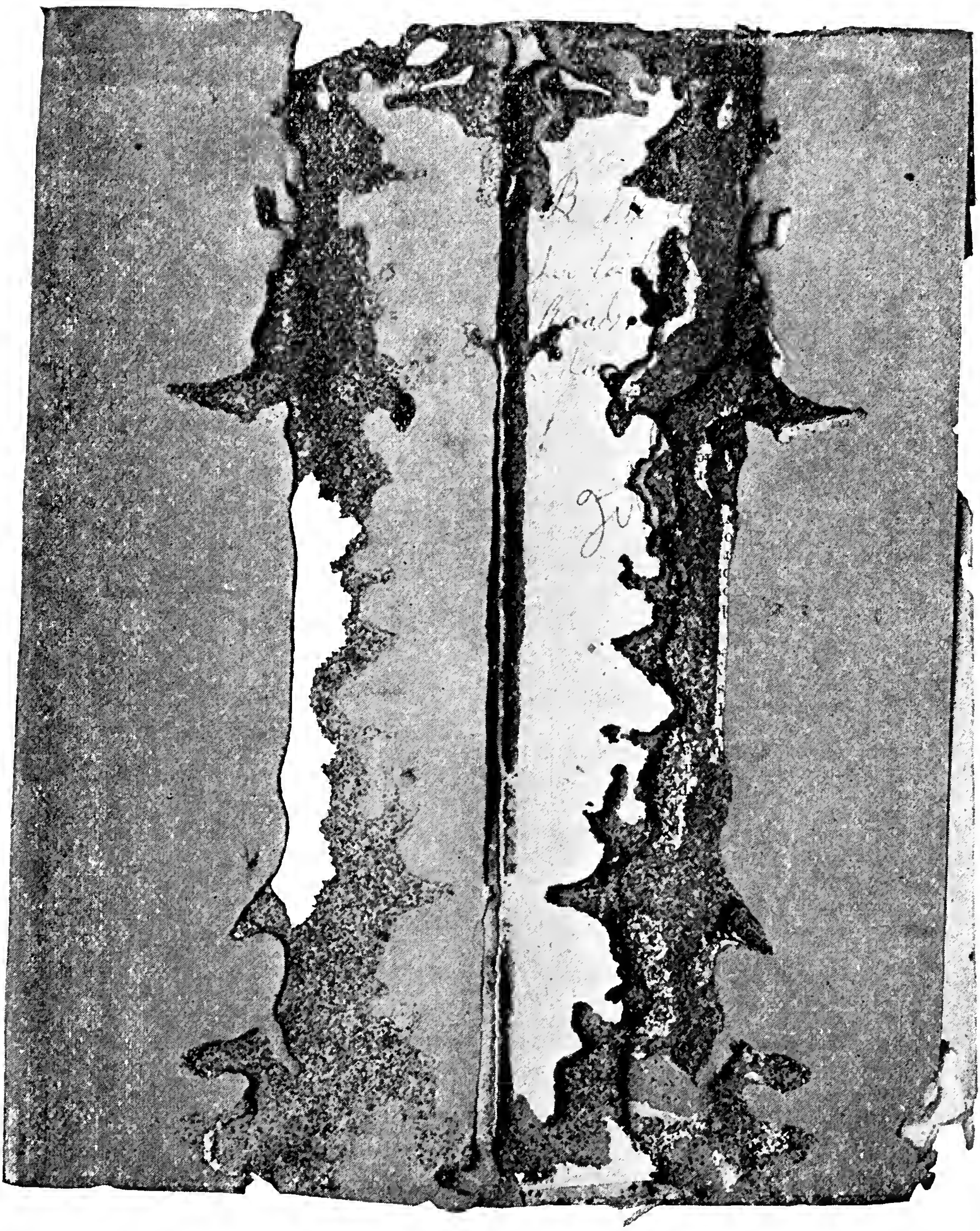
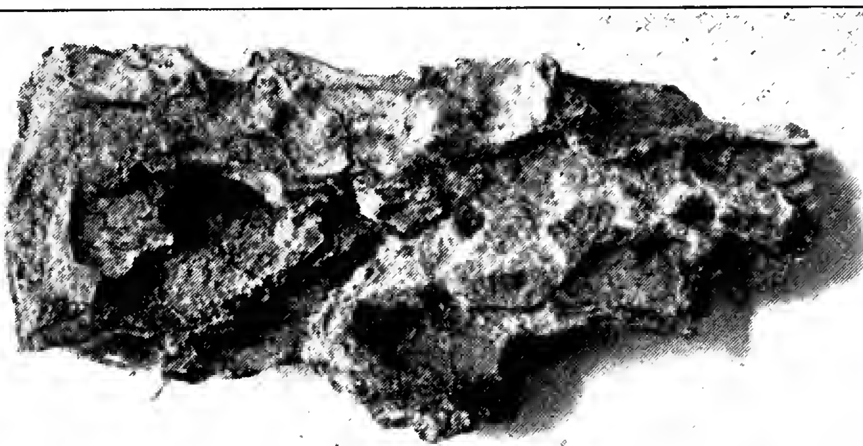


PLATE XIII



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APPENDIX

TO THE

Nineteenth Report of the State Entomologist

OF ILLINOIS.

ON THE

MEDITERRANEAN FLOUR MOTH

(*Ephestia kuehniella Zell.*)

By W. G. JOHNSON, A. M.,
ASSISTANT ENTOMOLOGIST.

PREFATORY NOTE.

The following article by Mr. Johnson, one of the entomological assistants of the State Laboratory of Natural History, detailed for service in the office of the State Entomologist, contains in part results of work done by him as a graduate student of Stanford University before his connection with this institution, and written up as a thesis for the master's degree. Much of his time has been given to the subject, however, since his engagement here, and a large part of the present paper is based upon results of this later work.

Although the Mediterranean flour moth has not yet been found to infest any mills in this State, its distribution in our vicinity makes it practically certain that it will eventually appear within our limits, and a comprehensive article on it is consequently even more timely than it would be if withheld until after the threatened invasion were an accomplished fact.

It is of great consequence to every miller that he should be not only forewarned of his liability to serious annoyance and heavy loss by the work of this worst of the pests of the flouring mill, but that he should also be thoroughly forearmed with information as to the signs of its presence, the characteristics by which it may be unmistakably recognized, and the measures of prevention and destruction to be used against it.

I have gladly availed myself, therefore, of this opportunity to put the millers of this State and of the country in possession of the essential facts, and to have compiled for the benefit of the working entomologist a complete review of the history and results of previous studies of this insect pest.

S. A. Forbes.

THE MEDITERRANEAN FLOUR MOTH (*Ephestia kuehniella* Zeller) IN EUROPE AND AMERICA.

BY WILLIS GRANT JOHNSON, A. M.

INTRODUCTORY.

Insect injuries in flouring-mills have been known from time immemorial, but not until recent years have they attracted public attention. The mild and equable temperature which is maintained in the modern mill is highly favorable to the development and multiplication of those pests commonly called "mill insects." The most formidable enemy in this group is the Mediterranean flour moth, *Ephestia kuehniella* Zell., an insect unknown to American millers less than seven years ago. The discovery of this terrible scourge in Canada in 1889, in California in 1892, and in New York and Pennsylvania in 1895, has awakened a keen interest in the subject among millers and scientifiic workers.

Its discovery in California in March, 1892, led me to a careful examination of all available literature on the subject. I found this material so scattered that I have deemed it advisable to bring it together and to embody it substantially in this paper which covers my own observations and experimental work on this insect. Most of these observations were made in California, where also a large part of my experimental work on life history and methods of destruction was carried on. Much additional information has, however, been gained by experimentation and correspondence since my connection with the Illinois State Laboratory of Natural History.

I wish to express here my thanks to Mr. L. O. Howard, U. S. Entomologist, Washington, D. C., through whose kindness I obtained Figures 1, 2, 3, and 5 from the U. S. Department of Agriculture. I also beg to acknowledge, with thanks, the kindness of Mr. James Fletcher, of the Department of Agriculture of Ottawa, Canada, in furnishing me with his exhaustive reports containing articles on this subject, and the courtesy of Dr. P. H. Bryce, Secretary of the Provincial Board of Health of Ontario, Canada, in sending me his excellent Bulletin and circular letter on the flour moth. I am also indebted to Miss E. A. Ormerod, late Consulting Entomologist of the Royal Agricultural Society of England, for her complete accounts of the moth in England; and to Mr. J. Danysz, Director of the Laboratory of Parasitology and of the Cham-

ber of Commerce, Paris, France, for his exhaustive and most important paper on this subject. I desire also to acknowledge here, with thanks, the help and coöperation I have received from the millers of California, New York, Pennsylvania, and Canada; and, finally, to express my appreciation of the favors received from Professor S. A. Forbes, Director of the Illinois State Laboratory of Natural History and State Entomologist, through whose kindness I am able to publish this article in its present form.

The names of all individuals and of firms on whose premises this pest is known to exist, have been omitted by special request, and I have carefully kept the confidence reposed in me. Such suggestions are offered as my experience warrants, and I trust this paper will enable all those interested to become better acquainted with this ravenous pest, and with measures for its control. In discussing the latter I have confined myself to methods which have been tested in large mills.

Before taking up my subject in a formal way it may be well to give, in a paragraph, a brief summary of the life history and habits of this insect.

The small gray moth, with a wing expanse of about seven eighths of an inch, is a sluggish insect, often remaining for hours in one position. The female usually deposits her eggs in spouts and elevators, or on piles of flour in bags, but they may be found in every conceivable place about a mill where there is sufficient food for the larvæ. The eggs hatch in about nine days, and the larvæ feed from five to seven weeks. It is during this period that the mischief is done. The larvæ have a peculiar habit of trailing a silken thread wherever they go, and this waste silk, mixed with flour and dust, often clogs the spouts to such an extent as to stop the machinery. About nine weeks are required for the transformations of the insect, reckoning from the time of the deposition of the egg to the emergence of the adult. It breeds continuously in warm mills, where the temperature is constant, and from four to six broods appear annually. It is usually disseminated in manufactured products, or on empty bags and second-hand machinery. It is comparatively free from the attacks of natural enemies, and when once established in a mill can be checked only by absolute cleanliness and the free use of bisulphide of carbon, sulphur, or steam.

ZOÖLOGICAL POSITION.

There has been much dispute among systematists regarding the zoölogical position of this little moth, and its name has consequently been the subject of much discussion. It belongs to the family of moths known as Phycitidæ, and was first given a scientific name in 1879, since which time it has been known as *Ephestia kuehniella*—a name given it by Prof. Zeller in honor of Prof. Kühn, Director of the Agricultural Institute of the University of Halle, Germany.

Mr. W. H. Patton, of Hartford, Conn., is responsible for the statement* that Dr. F. Karsch has shown that *kuehniella* and *interpunctella* are only dimorphic forms of one species. In 1884, Dr. Karsch gave it as his opinion† that *Tinea zeæ* of Fitch might prove to be a variety of *kuehniella*; and in an article in "Insect Life" for November, 1890,‡ under the caption "Notes upon *Ephestia interpunctella* (Hübn.) Zeller," Mr. Patton gives both *E. kuehniella* and *T. zeæ* as synonyms of *E. interpunctella.* Under the head of "Special Notes," the editors of "Insect Life" (l. c. p. 134) strongly dissent from Mr. Patton's conclusions, stating that they long since adopted *zeæ* as a synonym of *interpunctella*, but that they now fully believe in the distinctness of *kuehniella*, though inclined earlier to a different opinion.

Mr. Geo. D. Hulst, in his monograph of the Phycitidæ of North America,¶ has placed *interpunctella* in the genus Plodia, and left *kuehniella* under Ephestia. The main difference between the two genera, as indicated by Mr. Hulst, is that in Ephestia the palpi are erect, while in Plodia they are porrect.

Mr. Ragonot has shown§ that Mr. A. W. Scott's *Hyphantidium sericarium* evidently belongs to the genus Ephestia and, according to the description, closely resembles *kuehniella*; and he is of the opinion that the former will prove identical with the latter species, since its larval habits are precisely the same. For the present, however, Mr. Ragonot is content to let the species remain as *Ephestia sericaria* (Scott).

Mr. Hulst says (l. c., p. 199) that he has specimens from New Mexico which connect *Ephestia fuscofaciella* Ragonot with *E. kuehniella*, and he is of the opinion that the former may prove only a variety of the latter.

SPECIFIC CHARACTERS.

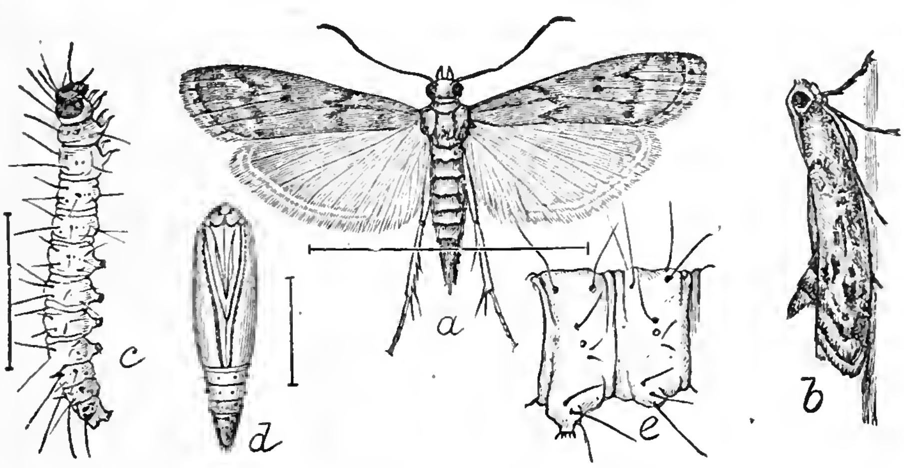

FIG. 1. *Ephestia kuehniella*:—*a*. moth; *b*. female moth, from side, resting; *c*. larva; *d*. pupa; *e*. abdominal joint of larva,—all enlarged, the hair lines representing the natural size. (*b*, *c*, *e*, from "Insect Life;" *a* and *d* after Chittenden).

Ephestia kuehniella (Fig. 1, *a* and *b*) is a delicate moth, from 10 to 14 mm. in length, with a wing expanse varying from 18 to 22 mm.** (about seven eighths of an inch). The females are, as a rule, larger than the males, but the general color and markings on the wings are the same in both sexes. Labial palpi blackish gray; head and thorax some-

*Insect Life, Vol III., p. 158.
†*Entomologische Nachrichten*, May, 1884.
‡Vol. III, p. 158.
¶Trans. Am. Ent. Soc., Vol. XVII., pp. 93-228.
§Ann. Ent. Soc. France (Bull.), 1892, p. CCLXXIV.
**Mr. Hulst gives 24-26 mm. (Trans. Am. Ent. Soc., Vol. XVII., p. 198)

what lighter; abdomen the same color, with an ocher shade. Front wings medium gray, sprinkled with blackish scales, crossed near the tips by two wavy angular blackish lines; a W-shaped transverse line about one third the way from the base; a black dot in the center, which is sometimes double. (See Fig. 2, *g.*) The hind wings are semi-transparent, of a silvery luster, with a darker border. Both pairs of wings are heavily fringed. (See Fig 1, *a.*)

The egg, plainly visible to the naked eye, is elongated oval in outline; greasy whitish in color when first laid, becoming darker as the embryo matures within; and varies considerably in length and breadth, as shown by the following measurements made from four different lots of eggs:

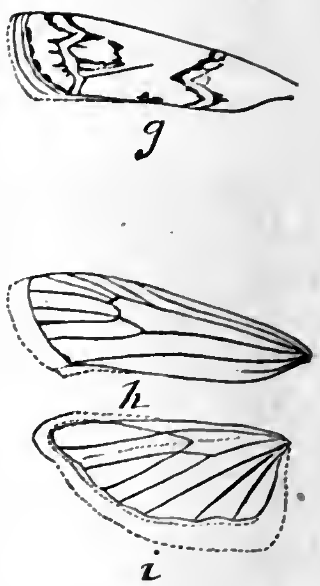

Fig. 2.—Principal markings and venation of wings. (After Snellen.)

First lot, laid April 12, 1895—Length, 0.432 mm.; breadth, 0.204 mm.
Second lot, laid April 17, 1895—Length, 0.480 mm.; breadth, 0.240 mm.
Third lot, laid May 5, 1895—Length, 0.408 mm.; breadth, 0.228 mm.
Fourth lot, laid June 19, 1895—Length, 0.444 mm.; breadth, 0.216 mm.

This variation in size occurs also in eggs of the same lot. The general average length is 0.441 mm., and the breadth 0.222 mm. The surface is irregular and has a crumpled appearance.

The larva (Fig. 1, *c*) when first hatched is very small, being only 1.083 mm. long, with a body diameter of 0.19 mm; head slightly larger, measuring 0.247 mm.; flesh-colored, varying from a whitish to a pinkish tint; head reddish brown; legs and prolegs a little lighter colored than body; body sparsely hairy, hairs longest on the posterior segments, often measuring there 0.342 mm., but about 0.114 mm. on the other segments. When full grown the larva varies from 12 to 14 mm. in length; form cylindrical, somewhat slender, with a rather uniform diameter of about 2 mm.; color as earlier, the pinkish tint more pronounced in some than in others. Three pairs of true legs, and a well-developed caudal pair; abdominal legs long, cylindrical, with a circular fringe of hooklets at the crown. Piliferous warts black or brown, rather minute but prominent; lateral ones more conspicuous in front of the first spiracle, the subdorsal ones, one each side of the mesothorax, almost completely encircled by a narrow black ring interrupted only at its upper margin. Each segment has six bristle-bearing dots, four of which are conspicuous and two smaller; a transverse reddish-brown patch on the segment next the head, divided, from front to back, by a faint central line; surface of body rather smooth.

The chrysalis (Fig. 1, *d*) varies from 9 to 10.5 mm. in length, and from 2.5 to 3 mm. in width. Reddish brown above, the head and thorax being darker than the rest of the body, much lighter below, the shade becoming lighter from the head back, approaching a yellowish tint on the wing-pads and abdomen; posterior part slightly curved and cylindrical; tip of the last segment considerably darker than the rest of the body and furnished with 9 or 10 stout brownish bristles, with their points curved, encircling the margin of the upper surface. Eyes prominent, usually of the same color as the head but sometimes darker; spiracles distinct.

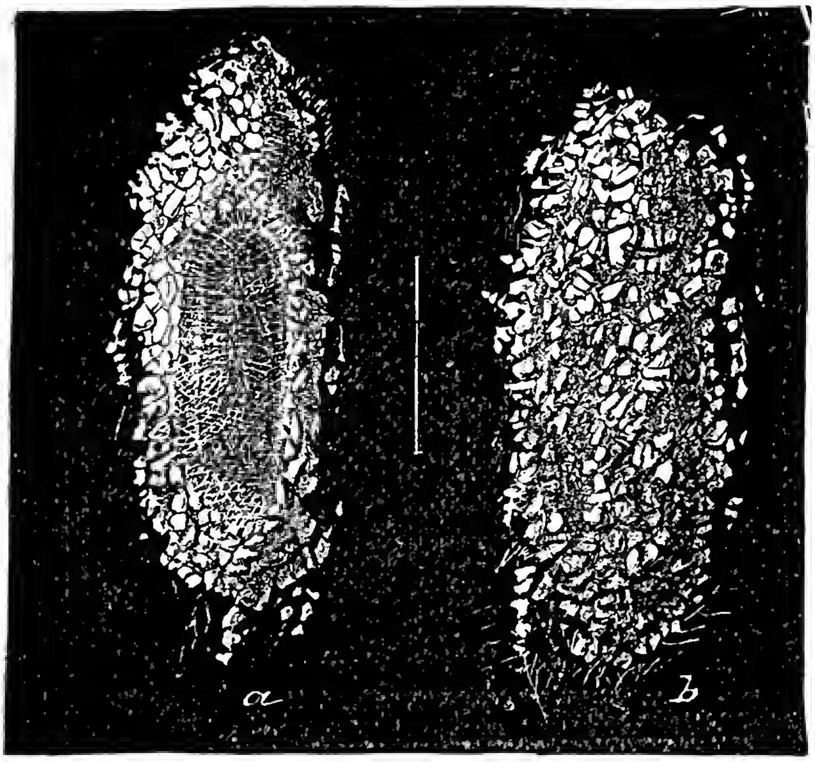

FIG. 3.—*a*, cocoon from below, showing pupa through the thin silk attaching the cocoon to a beam; *b*, same from above. Enlarged. (From "Insect Life")

The cocoon (Fig. 3, *a* and *b*) varies in length from 10 to 14 mm., and from 4 to 6 mm. in width. It is composed of very delicate whitish silk spun by the larva, and is often intermingled with particles of meal, flour, dirt, or other material. It is perfectly smooth within, and is usually attached to some surface by a very thin layer of silk, so that the pupa can be plainly seen when the cocoon is removed from its place of attachment, as represented in the accompanying illustration.

GENERAL REVIEW.

Although this moth was first discovered in a flouring-mill in Germany in 1877, it was not made known to science until 1879, when Prof. Zeller noted the outbreak and described and named the species (**1**)* from specimens from the infested mill, sent him by Prof. Kühn, Director of the Agricultural Institute, University of Halle, Germany. Prof. P. C. T. Snellen refers to this paper of Zeller's in 1881 (**2**).

The insect was next observed in a noodle factory in Belgium in 1884, and was reported by Mr. Alfred Preudhomme de Borre, July 5 of the same year (**5**). He supposed it to have been introduced into that country with American cereals. Many substances were used to rid the mill of the infestation, but they proved useless. The most noticeable improvement in the situation resulted from scrupulous cleanliness.

In May, 1884, Mr. Maurice Girard read a paper before the Entomological Society of France (**3**) on the ravages of the flour moth, which had appeared in a flouring-mill at Lodelinsarte, Belgium, and gave a short description of the adult insect and larva. In the discussion which followed this paper Mr. E. L. Ragonot said that he had in his collection specimens of *Ephestia kuehniella* from North Carolina, Mexico, and Chili. In this same year Dr. F. Karsch, in an article entitled "*Ephestia kuehniella*, Zeller: Eine Nord Amerikanische Phycide am Rhein," (**4**) notes the appearance of this moth at several places along the lower

* The full-face parenthetical figures in this paper refer to the bibliographical list appended.

Rhine. The ground color of the front wings of the typical specimens bred by Zeller was pure yellow or nearly brownish, while those bred by Karsch were glossy lead-gray, but Karsch considers them one species. The only moth he found in American literature that approached *kuehniella* was Fitch's *Tinea zeæ*, which is the same as *Plodia interpunctella*; but Fitch's description of the latter species did not agree with that of Zeller's species. Dr. Karsch thought, nevertheless, that *zeæ* might prove to be a variety of *kuehniella*.

In an editorial note in the *Entomologische Nachrichten* for 1885 (pp. 46, 47), the statement is made that this pest had appeared in some mills near Bremworde. The burning of sulphur and the application of bisulphide of carbon were found useless, and the mills were stopped and thoroughly cleaned. It is asserted that the insect, in that locality, is of American origin, and was introduced with American wheat. The same periodical, for the same year (pp. 239, 240), contains another note, reviewing a communication from Prof. Landois to the *Braunschweiger Tageblatt*, in which the statement is made that this pest is by far the most annoying and dangerous insect affecting wheat or flour.

Professor P. C. T. Snellen published in 1885 (**7**) an illustrated article of considerable importance on this insect, which included a summary of Prof. Zeller's article already referred to, and a comparison of *kuehniella* with other European species of Ephestia.

Mr. A. Seigel, German Consul-General at New York City, being asked by some of his countrymen to find out what he could regarding *Ephestia kuehniella* in this country, and to ascertain if possible the means employed for its destruction, addressed a letter on the subject to Dr. J. A. Lintner, State Entomologist of New York, under date of February 2, 1885, who replied that he had no knowledge of the pest as an American insect, and that if it existed in the United States it was as yet unknown, as no such habits had been manifested in any of our flouring-mills by any species akin to *Ephestia kuehniella*. He refers to *Plodia interpunctella*, and suggests several remedies for the destruction of the flour moth; viz., bisulphide of carbon, sulphur, and trapping. This, I believe, is the first published statement in American literature (**8**) regarding this pest.

The next note I find on this insect is by Mr. W. Thompson, of Stoney Stratford, Bucks, England (**9**). Larvæ found feeding on rice cones were given him by a friend in October, 1886, from which moths emerged during November and December. At first the insect was thought to be *Myelois ceratoniæ* and was so reported; but specimens sent to Mr. Barrett in April, 1887, were identified by him as *Ephestia kuehniella*. In the same volume of the same journal (**10**) Mr. J. W. Tutt gives a short account of the feeding habits of this insect, and records the breeding of the adult moth from larvæ given him by Prof. T. D. A. Cockerell, collected originally from a cargo of flour at the London docks. In June, 1887, larvæ from this same source were exhibited by Prof. Cockerell at a meeting of the South London Entomological Society. In the first published account of this exhibition (11) it is stated that the larvæ were in flour shipped from America to Trieste, and thence to London; but later (20) Prof. Cockerell states that although the larvæ just referred to were in flour from America, they were supposed to have come from some badly infested Trieste flour stored in the same warehouse.

In the same year Mr. C. G. Barrett (12) reports breeding moths of *Ephestia kuehniella* from larvæ sent him by Prof. Zeller in 1879; refers to the moths of this species sent him by Mr. Thompson for determination, noted above; and briefly describes the moth, noting ready means of distinguishing it from that of other species of Ephestia and from *Myelois ceratoniæ*.

November 2, 1887, Mr. Sidney T. Klein read notes of his observations on the habits of *Ephestia kuehniella*, at a meeting of the Entomological Society of London (13). He discovered in May a colony of these larvæ in some large warehouses in the east end of London, where the insect spread rapidly in spite of the fact that the building was fumigated with sulphur and the ceilings, walls, and floors were hot-limed. One entire warehouse was "literally smothered with larvæ, and several hundred pounds' worth of damage was done." Chickens introduced into the warehouse gorged themselves with the larvæ. Some interesting observations are reported concerning the habits of the larva, and it is said that a small hymenopterous parasite (*Bracon brevicornis* Wesm.) destroyed the pest by September. The same author gives elsewhere (14) full details concerning a lot of flour from Trieste infested with larvæ of the flour moth, referring again to the parasite, and in another connection (15) has an item concerning the introduction of the flour moth into England. The County of Middlesex Natural History and Science Society published a note by Mr. Archibald Geikie (17), in which he reported the complete destruction of *Ephestia kuehniella* by the same little braconid mentioned by Mr. Klein, figuring the male and female. He said, in substance, that he had noticed a black spot on the back of the flour moth larvæ which he had not observed before, but paid no attention to it, thinking it a normal phenomenon in the development of the insect. Some weeks later he was astonished to find on the sacks of flour, which had been covered with Ephestia larvæ, a great number of little black insects, and he was of the opinion that the black spots he had seen were nothing else than the eggs of *Bracon brevicornis*.

I will not call in question the correctness of this inference, as I know nothing about the life history of the European braconids, but will simply say in this connection that our two American species, *Bracon gelechiæ* Ashm. and *B. hebetor* Say, do not lay their eggs *within* the body of their host. I have made many observations on this point, and have always found the egg either *on* the body of the larva or attached to some material very near it. Mr. E. B. Poulton, of London, England, has, however, shown by experiment (21) that these black spots are simply testicles in the process of evolution. Mr. J. Danysz, of Paris, France, who seems to have overlooked Mr. Poulton's paper, has arrived at the same conclusion (**55**). In my own work I have found this a very convenient method for separating the sexes of the larvæ, and in no case has it been misleading.

In 1887, Mr. R. Adkin, of London, made two contributions to the literature of the flour moth (**18, 19**) which I have not seen. In an article published in 1892 (**45**) he states that the pest is still present in England, and that it is of sufficiently frequent occurrence in granaries, mills, bakeries, etc., to be regarded as an established insect pest.

In 1889, Miss E. A. Ormerod reports the appearance of the flour moth in very destructive numbers in England (**23**) and refers (**24**) to a new outbreak in a mill in the north of England in 1888, the larvæ getting into the spouts and machinery and, by their webs, stopping the flow of the flour. Some of this infested flour was found, on examination, to be little more than a webbed mass full of living larvæ, chrysalids, and dead moths. The mill was stopped and thoroughly cleaned, steam was introduced into every part of the place, and the walls and floor beneath were washed with "paraffine" (kerosene). The owner of this infested mill thought the insect came to him in empty sacks returned from some baker, perhaps coming originally from London in this way. In 1890 (**32**) Miss Ormerod reports the pest as still present in England, in one instance being kept in check by frequent fumigation, sulphur being the chief substance used. She gives the results of some inquiries regarding the presence of this insect in other countries, with a short abstract of matter in her Twelfth Report concerning the nature of the attack. Several paragraphs are quoted from Mr. Fletcher's Report for 1889 (**29**) and from a Bulletin by Dr. Bryce (**26**), both of which are referred to on another page of this article. In her Fourteenth Report (**38**) Miss Ormerod says that the flour moth may be regarded as thoroughly established in England and quietly extending itself, and that it is still doing serious damage in the mills from which it was first reported, although expensive preventive measures have been taken to keep it in check. The fact that this insect is present in widely distant parts of England is evidence of the root the insect has taken in that country.

There is no record of damage by this pest in North America prior to 1889, at which time it appeared in destructive numbers in a large flouring-mill in Ontario, Canada. The owner tried every means known to him to destroy the insect, but every effort failed, and he finally appealed to Mr. James Fletcher, Dominion Entomologist, for help. The matter was then brought officially before the notice of the Ontario Government, and the investigation was placed in the hands of Dr. P. H. Bryce, Secretary of the Provincial Board of Health of Ontario, who published the results of his investigation (**26**) in October, 1889.

The manager of the mill suspended work, and took down the machinery and subjected it to steaming. The whole mill was then thoroughly cleaned and fumigated with sulphur; the walls and ceilings were scraped and swept; elevator spouts, loose wooden work, paper bags, and many hundred dollars' worth of goods were burned; elevator cups and belts were boiled for hours in water; and those parts of the machinery not easily accessible, were flamed by means of a kerosene torch. All this was not sufficient, and September 19 the Local Government passed an Order in Council, compelling the manager of the mill to take more stringent steps for the suppression of the pest. In compliance with an order from Dr. Bryce, the miller constructed a tight steam box and subjected every piece of machinery, even millstones and iron rollers, to a thorough steaming. After two months' loss of time, and loss of fixtures and machinery, the mill started up again.

In his Bulletin (**26**), Dr. Bryce gives details concerning the habits and appearance of this insect in its various stages, and adds an account of its depredations in the past, drawing largely from Miss Ormerod's Twelfth Report. He suggests preventive and remedial measures in case the moth appears again in other mills.

Mr. Fletcher accompanied Dr. Bryce a part of the time during these investigations. They visited many stores and mills to find out whether the moth had spread, but in one case only was the insect found, and here, only such quantities of farinaceous foods were kept as would be sold out during the week to consumers. In his Report for 1889 (**29**), Mr. Fletcher says, "There was a general opinion among all those visited, that this insect was only the ordinary meal worm, *Asopia farinalis*, which may generally be found in small numbers in neglected meal or flour barrels, but which seldom does sufficient harm to be classed as an injurious insect." He further adds that "the present species may be considered a much more formidable enemy, and if allowed to multiply and spread through our large American flouring-mills, will be a calamity of enormous magnitude." A few months later the state of affairs in the infested mill was found to be very serious. Mr. Fletcher gives a brief summary of recent literature on this insect, with Dr. Riley's excellent figures of *Plodia interpunctella* and *Ephestia kuehniella* and comparison of the two species, adding information suggested by his own notes and observations.

In spite of the measures taken the year previous, the moth spread to other mills, and many local dealers in flour and grain had the pest on their premises. A printed circular letter was issued by Dr. Bryce, October 15, 1890 (**33**), offering to millers and produce men the coöperation of the Board of Health for the eradication of the pest A copy of the Provincial Act (47 Vic, chap. 38, sec. 39 and 40) is printed in this circular, according to which, among other provisions, any medical officer or sanitary inspector may at any reasonable time inspect a mill and examine the goods being manufactured for sale as food, and may condemn and order to be destroyed any food-products which may be found unfit for use. In addition to this, the person exposing them for sale shall be liable to a penalty not exceeding one hundred dollars for each parcel of grain, bread, or flour. In conclusion, Dr. Bryce reprints, from his former Bulletin, the remedies to be used in combating the pest.

In his Report for 1890 (**37**) Mr. Fletcher reviews his previous account of *Ephestia kuehniella*, and quotes several important letters from the manager of the first infested mill. The indifference on the part of those most interested is very noticeable, for one would naturally suppose that millers and produce dealers would have taken a little trouble to understand this matter, and to assist in carrying out measures which would be for their special benefit. A great many millers suffered severely for thinking there was nothing to fear when the moths first appeared on their premises. Mr. Fletcher says, "the steps taken by the Provincial Board of Health, and the milling company on whose premises the moth worked such havoc in 1889, have proved very satisfactory and were entirely successful. A few straggling moths were seen in the mill during the summer of 1890, but constant watching and scrupulous cleanliness finally rid the mill of the infestation." Mr. Fletcher gave an earlier account of this outbreak in Canada in a Report of the Entomological Society of Ontario (**30**).

The appearance of this moth in North America in 1889 in such destructive numbers called forth a timely article by Dr. C. V. Riley and Mr. L. O. Howard (**27**), in which the known facts regarding this pest are brought together in a condensed form.* Mr. Howard visited the Canadian mills the latter part of August, 1889, and accompanied Mr. Fletcher on a tour of inspection to the worst-infested establishment. The entire building was still completely overrun by this insect, notwithstanding the thorough-going measures which had been taken for its destruction. The principal studies on *kuehniella* mentioned in this article were, however, made upon material brought to Dr. Riley by Professor Panton, of the Guelph Agricultural College, during the summer of 1889; on material in the National Museum, containing specimens from Eufaula, Ala.; on five specimens from Europe sent by Mr. Ragonot; and on others from Germany, forwarded by Professor Zeller in 1883. The various stages of *Ephestia interpunctella* are figured in comparison with those of *kuehniella*, in order that both may be readily recognized, the early stages being quite similar.

In his excellent monograph of the North American Phycitidæ (**36**) Mr. G. D. Hulst cites some of the literature of *Ephestia kuehniella* and a short description of the species, indicates its distribution, and says that his specimens from New Mexico were taken in August and September. He refers to Zeller's original description and to Dr. Bryce's pamphlet, and quotes several paragraphs from the latter.

In August, 1892, Prof. T. D. A. Cockerell, then of the Institute of Jamaica, reported the appearance of this insect in Kingston, Jamaica. He found some oatmeal badly infested with larvæ which he supposed to be those of the Mediterranean flour moth, and accordingly issued a circular letter giving a short history of this pest, which was afterwards published in several daily papers in Kingston (**40**). April 1, 1893, Prof. Cockerell wrote me as

* I have made liberal use of the reviews contained in this paper, although I have carefully examined all the articles mentioned in it.

follows: "I hasten to make a correction on *Ephestia.* I wrote you October 27, [1892] that we had found larvæ of *E. kuehniella* here, but, although the larvæ seemed to be indeed that species, when the moths emerged they appeared different. So I sent some to M Ragonot, in Paris, and I have just heard from him that they are *Ephestia desuetella* Walker."

Several articles on this pest have appeared in French publications. The first, by P. Brocchi (**22**), in 1888. It contains a brief summary of the past history of this insect, and gives several methods, both preventive and remedial, for its arrest and destruction. Several papers on this subject have been written by Dr. C. Decaux, of France, referred to in the bibliography appended (**41, 42, 43**).

Mr. E. L. Ragonot (**49**) refers to the question of the origin of *Ephestia kuehniella,* calling attention to the fact that a species of the family Phycitidæ, discovered in the district of Wollombi, New South Wales, and described by Mr. A. W. Scott, in the Proceedings of the Zoölogical Society of London, 1859, under the name of *Hyphantidium sericarium,* belongs evidently to the genus Ephestia, and, according to the description, closely resembles *E. kuehniella,* but the plate shows two supplementary lines in the basillary space and another in the middle of the space, the imperfect crossing being replaced by a round dot. This slight difference he is inclined to lay at the door of the artist, and thinks that the species may prove to be identical with *Ephestia kuehniella,* the more particularly as its larval habits are precisely the same For the present, however, he is content to let the species remain as *E. sericaria* (Scott).

The most important publication that has yet appeared on this subject is by Mr. J. Danysz, of Paris, France, Director of the Laboratory of Parasitology and of the Chamber of Commerce. It is an illustrated article (**54**) of about sixty pages, and was published in 1893. It contains a summary of the more important articles previously published on this subject, a careful review of what has been said in regard to the origin and spread of the moth observations on its life history, and a discussion of the remedies used in various places for its suppression. As noted in the articles to which reference has already been made, European authors, excepting Miss Ormerod, have hitherto regarded this insect as of American origin, having been imported into Europe with American cereals. It will also be rememmembered that Dr. Riley and Mr. Howard, in their article on this moth which was published in "Insect Life" (Vol. II., pp. 166–171), protested against this haphazard conclusion, but with little effect upon the European authors who have since discussed this matter. Mr. Danysz concludes, after a careful review of the arguments brought forth by European writers, that it is unsafe to point to any one country as the original home of this insect. He is inclined to think that it was originally a very widespread species, and that it comes into prominence as a pest in flouring-mills at intervals when circumstances favor. He places no reliance upon the idea that it is being, or has been, imported in numbers from America into Europe.

Mr. Danysz has also written an interesting article (**55**) upon the pigment spots (embryonic testicles) of the larva of *Ephestia kuehniella*. While searching for the natural enemies of this insect, his attention was drawn to the published note of Mr. Archibald Geikie (**17**), referred to on p. 13. Mr. Danysz then segregated a number of Ephestia larvæ with the black spots upon their backs in the hope of securing some of the parasites, but his expectations were disappointed, for they all transformed successively to chrysalids and adults without presenting any abnormal features, while of the parasites he did not secure a single specimen. His close watch of the black spot, however, furnished him with a very interesting observation. By dissection he found that the pigment spot in question consisted of two reddish brown reniform corpuscles placed in the cellular tissue above the digestive tube, and that these same organs, a little modified, were easily recognizable in both the chrysalis and adult, so united in the latter, however, as to form a single ovoid body, connected by two long canals with the genital armature. The fact that larvæ with black spots always produce males, left no doubt that these organs were testicles in the process of development—a conclusion already reached by Mr. E. B. Poulton in the fall of 1888. (See p 16.)

In this same year (1893) Dr. F. Decaux published (**56**) a short illustrated article on *Ephestia kuehniella* in which he reviews its habits and suggests means for its destruction; and Prof. Lawrence Bruner, of the University of Nebraska, published a short illustrated article (**61**), which is principally a compilation from published reports on this insect, and was intended as a timely warning to millers and dealers to be on the lookout for it. In January, 1894, Mr. Gerald McCarthy published (**62**) a notice of the Mediterranean flour moth's presence in North Carolina, saying that it is likely to become a serious pest in that state.

In December, 1892, I sent out a circular letter regarding the flour moth, calling attention to its appearance in destructive numbers on the Pacific coast. This is, I believe, the first authentic record of its occurrence in the United States. The notice naturally interested the general public and several California papers (**46**) printed it. During the same month another newspaper (**47**) printed a reporter's account of an interview with me concerning this insect, and I published myself (**48**) a short account of its past history and appearance in California, with a review of the remedies used elsewhere for its suppression. I furnished an article of the same general character, for the January (1893) issue of "Milling", which was reprinted in another monthly journal (**50**) devoted to the same interest. The most important articles I have contributed on this subject appeared in the "American Miller" in 1895 (**67, 68, 72, 73**). In the March number (**67**) I gave a brief summary of former publications, a short sketch of the insect's life history, a preliminary account of my experiments, a review of the remedies used in various places, especially in California, and quotations from a large number of correspondents on this subject. In the May number (68) I announced the discovery of the pest in New York State, which is the first record of its occurrence in destructive numbers in mills in the United States east of the Rocky Mountains. In the October number (72) I gave a brief account of the methods now used in California and New York for keeping the flour moth in check, together with other notes and observations. In the November issue (73) I announced the discovery of a new parasite (*Bracon hebetor* Say) of this insect, and added a new locality. The facts which led to the discovery of the parasite are discussed somewhat in detail, suggestions are made for its colonization, and extensive notes regarding the new Canadian outbreak are given.

Mr. F. H. Chittenden, Assistant Entomologist to the United States Department of Agriculture, in an article entitled "The more Important Insects Injurious to Stored Grain," gives a short, somewhat popular account (71) of the Mediterranean flour moth. The article is illustrated, and contains the most perfect representation of the adult moth ever published. It is reproduced by permission on p. 9 of this paper. Mr. Chittenden also contributed some valuable notes previously unpublished.

In December, 1895 (74) I called attention to the fact that I had discovered *Bracon hebetor* Say feeding upon the larvæ of the Mediterranean flour moth, and further stated that I had bred a single specimen, a male, from the same lot of larvæ, which differed in many respects from typical specimens of *hebetor*, but was thought by Mr. Ashmead to be a small variety of the same species. *B. gelechiæ*, although not found on the flour moth, is mentioned, as it is closely related to *B. hebetor*; and reference is also make to the European parasites of this insect, *B. brevicornis* and *Chrymelus rubiginosus*.

I note next a communication from a Pennsylvania miller, Mr. E. Burns, who states (75) that he has been troubled with the flour moth in his mill for the last three years. He has been fighting it, principally, by keeping an extra sweeper, which adds about $500 per year to the running expenses of the mill. He says he tried sweeping his mill with steam some years ago, and found it worked well in the summer, when all the doors and windows were open, but as soon as cold weather set in he could not use this method, as the "steam on the cloths of the purifiers makes all good middlings run over the tail end of the machine." This information adds a new locality for the flour moth, as it has not heretofore been recorded from Pennsylvania.

Comments upon this outbreak and a few notes concerning the flour moth, with illustrations, were published (76) by me in January, 1896; and in February I replied (78) to a query from a milling firm in Melbourne, Australia, who had forwarded me for examination a sample of flour matted together in a way to suggest the work of the flour moth. No insects were found in it. An illustration accompanying my reply shows a sample of wheat flour felted together by the flour moth.

Prof. William Trelease, of the Shaw School of Botany, St. Louis, exhibited at the February (1896) meeting of the Academy of Science of St. Louis (**79**) specimens of a curious silk fabric taken from the ceiling of a corn-storing loft in San Luis Potosi, Mexico, by Dr. Francis Eschauzier. Although specimens of the insect responsible for the silk were not secured, it was presumed that it was made by larvæ of the Mediterranean flour moth.

Besides the articles already mentioned, several reviews and notices have appeared in other publications, principally in "Insect Life," all of which are mentioned in the list at the end of this paper.

DISTRIBUTION AND DISSEMINATION.

As has been already stated, *Ephestia kuehniella* was first brought to the attention of scientists in 1877. Prof. Zeller, two years later, when he described it, stated on insufficient grounds that in all probability the insect came from North America. It was supposed to have been introduced in Belgium, in 1884, on American cereals. Regarding its appearance in mills near Bremworde in 1885, it is stated positively that the insect was introduced in that locality on American wheat. This being in the Belgium and Bremworde mills at the time of the outbreak, seemed to suggest to those concerned that the pest must be of American origin. The fact of the case is, that the pest was not known in North America in destructive numbers prior to 1889, at which time it appeared in Canada. The moth has been known much longer in Europe than in America, but the extreme readiness with which Europeans attribute new pests to this country, has been exhibited more than once.

Miss Ormerod did not find *Ephestia kuehniella* listed in Grote's check list of the moths of North America for 1882, and was therefore of the opinion that the pest came to England from Europe or the East, rather than from America. Mr. Sydney Klein, in the "Mark Lane Express," 14th November, 1887, in speaking of the English outbreak, says the pest was introduced into the London warehouse where he carried on his observations, in some meal shipped from Fiume, on the Adriatic, in 1885. I might state here, that Mr. Klein mentions this pest as the scourge of the Mediterranean ports, but does not give any date as to its first appearance there.

In 1890 Miss Ormerod made inquiries regarding the distribution of the moth, and received a letter from Dr. Lindeman, of Moscow, stating that he was not aware of its being present in Southern Russia, and that it had not been observed in Central Russia up to that time.

Mr. J. Danysz, of Paris, has made a careful study of the outbreak in France, and states that its first occurrence there is recorded prior to its first appearance in England. He does not think it safe to point to any one country as the original home of the pest, and places no reliance upon the idea that the insect was introduced into Europe from America. He calls attention to the fact that Halle, Germany, where the pest was first observed in 1877, is an inland town, as is also the place where the moth was first observed in France, and concludes that circumstances will not sustain the theory of the original importation of the insect into either Germany or France. A practical miller assures Mr. Danysz that he has known of the pest in the neighborhood of Paris for the last fifty years, and that he remembers a case of serious damage as early as 1840. Another miller asserts that he knew of a serious outbreak of this insect in a flouring-mill in Constantinople in 1872; that it was very troublesome for two years, and then disappeared.

Dr. Selmar Schonland, Curator of the Albany Museum, Grahamstown, Cape Colony, wrote Miss Ormerod in 1890, that inquiry had been made regarding a moth, or rather, larva, which was doing considerable damage in flouring-mills in King Williamstown. I do not know whether this was *Ephestia kuehniella* or not, but judging from the account of the damage done, I am inclined to think it was.

Regarding the introduction of the pest into Canada, Mr. Fletcher says there is some doubt as to the time when the first specimens came, and also concerning their origin; but evidence seems to point to a consignment of goods imported from Mediterranean ports in 1887. Mr. Geo. P. Hulst, in his monograph of the Phycitidæ of North America, in speaking of the flour moth, says: "I do not know that it has given trouble in California, if indeed it exists there (1890). It has, however, developed very rapidly in Europe, becoming a very great evil. The 'Ontario Bulletin' speaks of its having come from Europe, though there is no reason why it should not have come from the Pacific coast." With reference to the present Canadian outbreak, so far as I can learn, the pest seems to have been in local mills for some time past, and as these mills are in an inland town, it would be a difficult matter to trace the moth to its original source.

Notwithstanding the fact that this insect was not noticed in North America until 1889, evidence seems to point to its presence in this country some years earlier. Mr. Danysz has traced its occurence in America as far back as 1880. As stated by Dr. Riley and Mr. Howard, specimens from Alabama, indistinguishable from *Ephestia kuehniella*, were in the Natural Museum collection at the time of the Canadian outbreak. Dr. Riley states also that he had seen specimens from North Carolina in Mr. Ragonot's collection in Paris. It is also recorded from Colorado and New Mexico, and was found in a Mexican exhibit at the World's Fair in Chicago; and it has been found in Chili and probably occurs in Australia and South Africa. However long the pest may have existed in North America, no record of any damage is recorded prior to 1889; and the California outbreak, first observed by me, is positively the first record of any destruction by this pest in the United States.

The moth seems to have appeared in great numbers in certain localities for a time, and then disappeared. Prof. Zeller wrote Dr. Riley in 1883 that the insect had apparently died out at Grünhof; and, as stated above, Mr. Danysz was informed by a practical miller that it appeared in destructive numbers in a flouring-mill in Constantinople in 1872, and disappeared after two years. This might seem to indicate that the insect is a passive creature, and if not disturbed, and allowed to multiply for a time, would finally disappear altogether; but so far as I can learn, it has never disappeared from a given locality or mill only after the most energetic fighting.

There is not much doubt but that the moth existed in widely separated places a long time before 1877. As stated above, Mr. Danysz has collected some important information on this point from practical millers in France. I have been informed by a thoroughly reliable miller in San Francisco, whose name I withhold by request, that he came in contact with this pest in 1858. At that time he was employed in a large flouring-mill at Rastdorf, near Kiel, Schleswig Holstein, Germany, where the moth was very abundant during the month of June. He is positive about his identification of the insect, having had much experience fighting it in his California mills since 1889.

The foregoing facts indicate that *Ephestia kuehniella* was thoroughly established in Germany twenty years or more before it came into Prof. Zeller's hands for description, and it is therefore unlikely that the pest was introduced into that country from North America. From all I have been able to gather on this point I am of the opinion that its original home, if ever ascertained, will not be North America.

It has been recently discovered that this moth lives in the nests of a wild bumblebee in California, and Mr. D. W. Coquillett, of the U. S. Department of Agriculture, is reported by Mr. F. H. Chittenden as having stated that it also occurs in the hives of the honey-bee. The question naturally presents itself, has the moth found that it can perpetuate its species in a bumblebee's nest or a beehive, and transferred its attack from the mill to these more natural and primitive food houses, or *vice versa?* The theory that the transfer has been from the bumblebee's nest and the beehive to the mill would afford a plausible explanation of the appearance of the moth in mills in isolated places, and at times when it was least expected. The origin of the California outbreak might be thus explained; but I have myself no faith in this theory concerning the present infestation, and will not discuss the matter further from this standpoint.

I will now state as briefly as possible the facts I have gathered regarding its occurrence on the Pacific coast. I have been told by prominent millers in California, that it has been less than fifteen years since oatmeal was bought in the Eastern States, shipped to California, and sold cheaper than it could be manufactured there. I do not infer from this that the moth came through this channel, but simply introduce the statement to indicate the commercial relations that existed a short time ago between the Pacific coast and the Eastern States. Had we known positively that the moth existed in the United States east of the Rocky Mountains during this period, we might have been a little hasty in accounting for its presence in California. I am reported as having stated * that the pest was probably introduced into California on second-hand machinery brought from a Chicago mill which was in communication with the Ontario mills. I had been informed that the machinery in question came direct from Chicago to San Francisco, being stored in the mill where the pest soon afterwards appeared in great numbers, flying in and out of cylinders connected with the apparatus. I have since ascertained that the machinery, although purchased in Chicago by a California firm, changed hands several times in San Francisco before it reached the mill where my first observations were made, being in the meantime in a mill—since burned down—where the pest was known to exist. This seems to indicate that the moth was introduced into the former mill from a neighboring one and not from Chicago.

A prominent miller in San Francisco informs me that his mill was overrun by this pest in the early part of 1889, soon after the introduction of a large quantity of rice from Sicily. He is of the opinion that the moth came to him with this rice. This is not certain, since it was observed about the same time in neighboring mills in which rice was not kept. After interviewing the owners of many larger mills in California, I found that the pest, in all cases, was first noticed during the early months of 1 89. This indicates that the introduction must have been a general one, as the outbreak occurred at the same time in widely separated mills.

The manager of the mill which has been the principal seat of my observations, tells me that he purchased the machinery mentioned above from an oatmeal company in San Francisco, which has since discontinued business, and transferred them to his premises. They were bought in the spring of 1890, and were stored in the attic of his mill. About three months later he noticed some moths flying in and out of cylinders connected with the apparatus, and fearing they might be the same pest that had appeared in Canada, he took immediate steps for their extermination, closing the end of the cylinders and burning sulphur inside. He says, regarding this outbreak: "This entirely destroyed the moths in the cylinders, but about six months later a more energetic fight was required, the mill being then thoroughly swept and fumigated with sulphurous fumes, with good results."

I have positive proof that the moth is established in mills in the following California localities· San Francisco, Oakland, Sacramento, Port Costa, Stockton, and Woodland. It is only a matter of time—unless millers keep the pest in check more effectually than at present—before every miller in that state will have *Ephestia kuehniella* to combat.

There is a good deal of uncertainty about the origin of the flour moth in New York State. From what I can ascertain by correspondence, the pest is pretty generally distributed throughout

* "San Francisco Call," Dec. 6, 1892.

the southwestern part of that State. It seems to have been first observed in the early part of 1893, and has been spreading from mill to mill until it is now established in mills in several counties. I cannot find any printed account of its presence there previous to my own announcement of it in March, 1895.

Dr. J. A. Lintner, the State Entomologist, stated, in a letter written in February, 1885, that he had no knowledge of the flour moth as an American insect, and that if it existed in the United States it was unknown to him. I cannot venture even the slightest hint as to the source of this outbreak in New York. Suffice it to say that the pest is well established in several interior counties in the southwestern part of the State, and, from present accounts, is spreading to others. The latest information I have on this subject is contained in a communication to the "American Miller" for December, 1895, (p. 910) from a Pennsylvania miller living in the vicinity of the New York outbreak.

Considering the ease with which the flour moth is carried from place to place, it is not surprising that we hear so much concerning its ravages. The eggs, larvæ, and pupæ are transferred long distances in manufactured products, and the conveyances themselves very often become sources of infestation. Ships, canal boats, freight cars, or even wagons that carry large quantities of grain, flour, or other farinaceous products, afford excellent breeding beds for this pest, which is usually transferred to the warehouse, mill, store, or private residence with the material. The fact that the adult moth is capable of living from seven to nine days after maturity, seems to indicate that it may fly a considerable distance; and in large cities where many mills are operated, it is quite possible that the parent insect often finds lodgment in such places after long flights. The moth, however, is not a rapid flyer, and alights quite often, the distance between flights depending on the surroundings. In a California mill I have seen the adults fly the full length of the building (a hundred and ten feet) before lighting. In the open air no doubt the flight would be much longer.

Owing to the minuteness of the eggs, and to the fact that the larvæ are almost always concealed, these two stages are the most readily transferable. Eggs deposited on sacks of flour and on other manufactured products in the mill, are carried away unnoticed with the material, and the pest is thus given a large local distribution, finding lodgement in warehouses, grocery stores, livery and feed stables, hotels, and private dwellings. Mills in the vicinity of such places are liable to become infested from them, by the return of old bags or barrels.

The pest is sometimes transferred long distances in second-hand machinery. In April, 1894, a Stockton, Cal., miller wrote me as follows: "Referring to yours of the 3d inst., relative to the Mediterranean flour moth, would state that I have known of it for some years, and for the past eighteen months we have had it with us here. Although its presence is not at all desirable, still we have suffered no damage or inconvenience from it, unless, perhaps, we have had to exercise a little more vigilance in keeping the mill thoroughly clean. We introduced it here by purchasing a machine that was for a short time in one of the San Francisco mills. We have not used sulphur nor done anything to eradicate it, excepting to increase our endeavor towards cleanliness." An instance of this same nature is given on p. 28, the moth being introduced on some apparatus bought from a local firm in whose mill the pest had a firm foothold.

As a rule, the moth is transported carelessly on bags and machinery. The former is, however, the commonest and greatest source of danger, and extreme care should be taken lest the pest is introduced in this manner. All bags which have been used for transporting grain, flour, or meal should have no entry to a mill until subjected to a thorough fumigation with bisulphide of carbon or with steam. Preventive measures are treated in detail on subsequent pages of this paper.

CHARACTER AND EXTENT OF INJURIES.

The larvæ of the Mediterranean flour moth would not be such a pest to millers were it not for the strange peculiarity they have of trailing little silken threads as soon as they begin to crawl. This silk is usually mixed with flour and dust, and looks and feels like a handful of cobwebs rolled loosely together in a flour bin. The mass of flour and web represented in Fig. 4 gives a fairly good idea of its condition. This particular material was taken from a spout in a New York mill last April, from which a photograph was made and reproduced. It is this waste silk that troubles millers most. When hundreds and thousands of these larvæ are at work in a spout, elevator, or other portions of machinery, this silk accumulates rapidly, piles up in tangled masses, clogs the machinery, and very soon stops it entirely. Then the whole plant must be taken apart and cleaned.

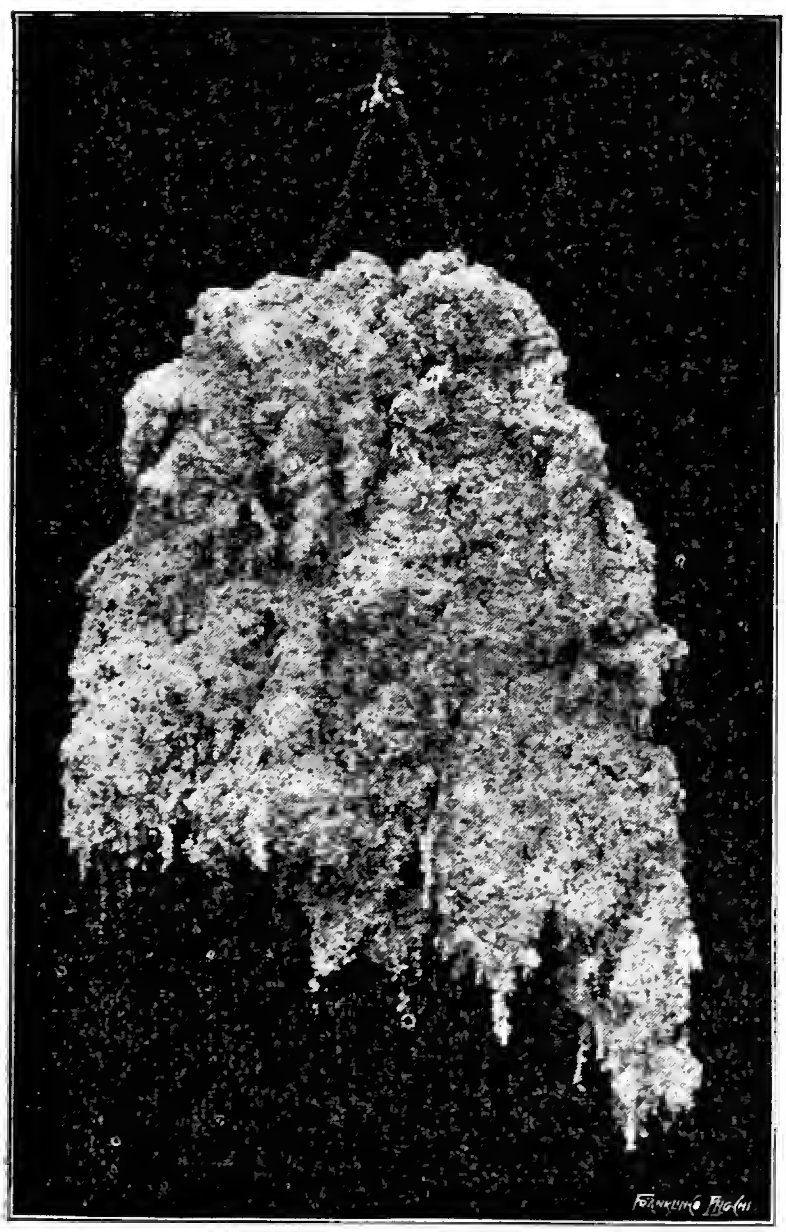

Fig. 4.—A mass of flour webbed together by the flour moth larvæ. (Original).

One of my California correspondents sent me the following note on this subject: "We find more trouble with the pest in the spouts and elevator legs than in any other portion of the mill, since these parts of the machinery are kept closed and the moth can breed there without being disturbed. Some of the elevator legs have been so closed up that there was scarcely room for the elevator to travel, and many of the spouts have been so completely choked up that it was necessary to take them down and remove the web, larvæ, and pupæ before the stream of stuff could pass through them."

The magnitude of the attack depends somewhat on the time of the year and upon the nature of the products manufactured. In the eastern states, and also in California, the larvæ are most abundant during the summer months, but in California the climate is so even that but little variation is noticed at different times of the year.

The larvæ are particularly found of products manufactured from rice, and in mills where this is the principal cereal handled that department is worse infested than others. Buckwheat flour is also a favorite, and the larvæ will pass over oatmeal and wheat flour in order to get to this product; but in mills where rice and buckwheat are not handled, they attack any cereal product. The parent insect may deposit her eggs in any part of the mill where the young larvæ can find food, but in the great majority of cases the eggs are laid where the conditions are most favorable for the development of the young larvæ. The spouts and elevators are therefore worse infested than other parts of a mill. In a mill where flour is stored in sacks, the female pushes her ovipositor through the meshes of the sacks and places her eggs within the flour. I have carefully observed this point, and have found that three fourths of the eggs are deposited in this way, when such places are chosen for their deposition. Such flour may be perfectly free from larvæ when sent out from the mill, but in a few days the young creatures hatch from the eggs within it, and the flour is soon matted together and is unfit for use. The larvæ get into most manufactured products in this manner, the eggs of the moth being usually packed with the material.

It has been reported by some European writers that the larvæ attack the bolting-cloth, but I have made no similar observations. I have found many larvæ on and about the screens in mills, but have never seen one attack the cloth. In my breeding-cage experiments I have no difficulty whatever in this direction. All my cages are covered with fine Swiss muslin, and I have no trouble in keeping the larvæ within. To see whether, in confinement, they would attack bolting-cloth, I procured some of this material from a miller in California, and covered two cages with it. The larvæ matured, and pupated in most cases in the top of the cage, usually forming their cocoons on the under surface of the cloth, but in no case was it punctured by them. I am of the opinion that in the cases reported the injury to the bolting-cloth was due to that cosmopolitan creature, the cadelle (*Tenebrioides mauritanica*). I have seen both larva and adult of this insect cutting bolting-cloth, and have found it in every mill I have inspected. In California it is known as the "bolting-cloth beetle."

The Ephestia larvæ thrive best on the more glutinous cereals, but they infest all manufactured foods prepared from wheat, oats, rice, Indian corn, and buckwheat, and will attack the grain itself, to a limited extent, when the manufactured products are not available. While a resident of California, being suspicious of all breakfast foods purchased for my table, I closely inspected every package, and found flour-moth larvæ in oatmeal, corn meal, rolled wheat, and germea bought at a local grocery store. They also feed on crackers, and have been found in bumblebees' nests and in beehives, feeding probably upon the wax and bee-bread. Mills in which several kinds of cereals are prepared for food are not troubled equally in all departments. For instance, where wheat flour, oatmeal, and buckwheat flour are manufactured, the oatmeal is more infested than the wheat flour, and the buckwheat worse than the oatmeal. The manager of a California mill wrote me with reference to this subject as follows: "I have observed that they seem to thrive best in buckwheat flour. I have never been able to understand why they should prefer this flour, but we have to be exceedingly careful of this food, or in a short time it will become full of webs spun by the larvæ." The manager of a Canadian mill wrote Mr. Fletcher the following: "If this insect strikes a mill where a variety of cereal products are manufactured, it will work its way into every product, though it likes glutinous substances best. It attacked every thing we made, from pot-barley to fine farina and milk food in tins" In a mill, where rice foods are the principal product manufactured, the manager tells me the rice is more attacked than any other cereal. He said they were much troubled with the larvæ in food put up in tin cans lined with tissue paper, very often having the goods returned, marked "wormy."

DEVELOPMENT.

By a long series of experiments, conducted in California and Illinois, I have ascertained that the life cycle of *Ephestia kuehniella* under the most favorable conditions, from the time the egg is deposited until the adult moth emerges, is about nine weeks.

Mr. Danysz has found that the period of development in France is about the same, insects in his experiments having completed the life cycle in from two to two and a half months. Professor Landois is of the opinion that during warm weather, in Germany, the larva of the flour moth develops into the adult within four weeks. In speaking of the outbreak in warehouses in London, Mr. Klein says: "The larvæ, which were full-fed in about three weeks, then made their way to the surface." It is hardly safe to assume that this represents the full life cycle of the larvæ, as the exact date of hatching was not recorded.

In connection with the Canadian outbreak, Mr. Fletcher says: "There are probably two normal broods of the flour moth, one emerging in the spring, and another in the autumn; but in a jar kept constantly under observation in my office, which was heated during the winter, there have been, I judge, three distinct broods; although from the fact that some retarded individuals have been emerging the whole time, and no special study made of them, it is very difficult to keep track of the separate broods."

Mr. F. H. Chittenden has estimated, from experiments recently conducted by him in Washington, that in the warmest weather the life cycle is about five weeks. In my experimental work during midsummer, under the most favorable conditions, in California and Illinois, I have been unable to get a full grown larva in less than five weeks from the time it emerged from the egg.

The number of annual broods of this insect depends largely upon the geographical location and upon the condition of the mill. In California, where the climate is even, the amount of damage done and inconvenience caused varies but little with the time of year. In the Eastern States, however, the insect is most troublesome during the summer months; although in exceptionally warm mills it is very annoying even in midwinter. I have shown by a series of carefully planned experiments that there are from five to six annual broods in California, and probably the same number in some of the Southern States and in Eastern States where the mills are well heated during the winter months. In most cases, however, in the East, four broods seem to be the average, appearing most abundantly from April to December. Brood after brood have appeared successively in my cages for the past two years.

From a long series of experiments, I have selected five representing the life cycle of this insect, the eggs being deposited in April, August, and October. The results are given in the following table:

EXHIBIT OF OBSERVATIONS ON LIFE CYCLE.

Experiment.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Source of material	California	California	New York	New York	New York
Experiment conducted in	California	Illinois	Illinois	Illinois	Illinois
Adults found pairing	Aug. 1, 1892	Oct. 25, 1894	April 11, 1895	April 11, 1895	April 29, 1895
First eggs deposited	Night of Aug. 1, 1892	Night of Oct. 25, 1894	Night of April 11, 1895	Night of April 11, 1895	Night of April 29, 1895
Total No. of eggs deposited	217	220	271	259	227
First eggs hatched	Afternoon of Aug. 8, 1892	Forenoon of Nov. 3, 1894	Forenoon of April 21, 1895	Noon of April 21, 1895	Afternoon of May 7, 1895
First fully matured larvæ	Forenoon of Sept. 27, 1892	Forenoon of Dec. 18, 1894	Forenoon of May 26, 1895	Afternoon of May 26, 1895	Forenoon of June 12, 1895
Cocoon begun & completed	Sept. 28, 1892	Dec. 20, 1894	May 28, 1895	May 27, 1895	June 13, 1895
First adult moth emerged	Morning of Oct. 9, 1892	Noon of Jan. 1, 1895	Morning of June 12, 1895	Morning of June 12, 1895	Noon of June 28, 1895

From the above table we see (1) that the period of incubation for the eggs varies from seven to nine and a half days, with an average of eight and two fifths days; (2) that the feeding stage of the larvæ varies from thirty-five to forty-nine and a half days, with an average of forty days; (3) that usually from one to two days elapse after the larvæ are full grown before the cocoon is spun; (4) that the chrysalid stage lasts from ten and a half to fifteen days, with an average of thirteen days; and (5) that the period from the time the eggs are deposited to the emergence of the moths varies from fifty-nine and a half to sixty eight and a half days, with an average of sixty-three and three fifths days, or about nine weeks.

Copulation takes place, in most cases, the same day the adult emerges, usually in the early morning, lasting from four to five hours, but oftentimes extending over a period of eight to ten hours. A single female will pair several times, and a male that was seen pairing on two different occasions on two successive days, on being removed to another cage, in which a freshly emerged female was placed April 11, 1895, paired again the same afternoon. The eggs deposited by this female that same night, hatched just ten days later, thus proving their fertility. The female has a peculiar habit of resting with the anterior end of her body somewhat elevated, the wings slightly spread, between which she projects the tip of her abdomen, as shown in the illustration at *b* on page 9. Oftentimes she also extends her ovipositor from an eighth to a quarter of an inch (not represented in the figure), giving the abdomen the appearance of ending in a long spike. The female will assume this attitude for several days, or until copulation takes place. I have had as many as twenty five females in a cage at a time, where they often remained five or six days in this characteristic position before any males emerged. They are rather sluggish while pairing, and can be easily transferred from one cage to another without being separated.

The female usually deposits her first lot of eggs the night after the first copulation, and so far as my observations and experiments go, they are laid at night only. The egg-laying period of a single individual lasts five or six days, during which time an average of about two hundred and forty eggs are deposited. In mills they are usually deposited singly, but may often be found in chains of eight to ten. The largest number I have succeeded in getting from a single female is two hundred and seventy-one, and the smallest one hundred and twenty. The total number deposited by each individual in the above experiments is listed in the table. The female lives only two or three days after the eggs have been deposited; and the average life of the male after pairing is from six to seven days.

Professor H. Landois, of Münster, Germany, ascertained by an anatomical examination that the eight ovaries of an *Ephestia kuehniella* contained respectively, 66, 79, 80, 84, 85, 87, 92, 95 eggs, an aggregate of 668.

I have dissected a great many fully matured females, some immediately after pairing and others just before, but have not obtained any such results as those tabulated by Professor Landois. The greatest number of eggs I have obtained by dissection is 342, and the least number 187. I have also carefully examined a series of females after death, immediately after the eggs had been deposited, to see if any undeveloped eggs were left in the ovaries, and in five cases found they were completely spent, while I found seven eggs each in three others, fourteen in another, and twenty-six in another. This would seem to indicate that the total number of eggs in the ovaries does not represent in all cases the total number that may be laid by a single individual. As stated above, the greatest number of eggs I have yet obtained from a single female is 271 (No. 3), and an examination of the parent insect later showed that the ovaries were spent.

A correspondent of mine in California was asked by me to conduct a series of experiments in his mill during the month of November, 1892, to ascertain the exact time required for the incubation of the flour-moth eggs, and on December 5 I received the following reply: "The eggs hatch in my mill, under the most favorable conditions, in a trifle less than nine days." This is in accordance with my own experiments. Mr. James Fletcher says that caterpillars emerged in December, in a warm office, about nineteen days after the eggs were laid. I cannot account for this difference in time, as eggs deposited December 4, 1894, kept in my office where the temperature ranged from 38° to 72° Fah. hatched in exactly nine days. As has been shown by Mr. Danysz the development of the embryo is greatly retarded by a continuous low temperature, and it is possible that the eggs in Mr. Fletcher's office may have been exposed to a lower temperature than 38° Fah. for a considerable length of time, which would, possibly, explain the difference in the period of development. Another point to be taken into consideration is the fact, that the female is from five to six days in depositing her eggs, and that there is a difference of as many days in the hatching of the first-laid and the last-laid eggs of the same generation.

The active or feeding stage of the larva depends upon the temperature of its surroundings, and upon the kind and amount of food. Larvæ hatched from eggs October 9, 1894, were divided into two lots and placed in breeding-cages with wheat flour for food. One cage was placed in the insectary where the temperature varied from 28° to 78° Fah., and the other was kept in a warm office at a temperature of 48° to 82° Fah. Larvæ in the former lot were fully matured November 26, or in about seven weeks, and in the latter November 13, or just five weeks from the time they emerged from the eggs. In other experiments conducted to test the effect of the amount and kind of food on the larvæ, I have had varied results. Larvæ feeding on coarse corn meal, for example, did not mature as quickly as those in the same room fed on wheat or buckwheat flour. As already stated the average active period of the larva is about forty days; but under the most favorable circumstances this stage is reduced to about five weeks. Mr. James Fletcher writes that moths kept in a breeding cage in his study, continued to emerge and lay eggs until December 15. He then adds in a foot-note, that larvæ from these eggs were full grown March 21. This makes a period of ninety-five days, and would seem to indicate that in Canada the development of the larva is very much slower than in California, or in Illinois and New York, during the winter months, as in no case have I observed the larval period to last longer than forty-nine and a half days.

When the larvæ reach maturity they have the peculiar habit of migrating to some isolated corner for pupation, and will then leave their feeding quarters provided an outlet is afforded. It is difficult to confine them in a breeding-cage at this period, and in my cages many larvæ have escaped by working their way out underneath the stout rubber bands which held the muslin over the cage. After maturity the larva will often crawl about for one or two days, without taking any food, before finding a suitable place for its quiescent stage. The cocoon, in which the chrysalid rests, is made of fine silk, often intermingled with particles of flour or meal. These cocoons are sometimes found in great masses in the most remote parts of a mill. The adult moths emerge in about two weeks, and deposit their eggs for succeeding generations.

Mr. Sidney T. Klein, in a paper read before the Entomological Society of London, refers to the peculiar migratory habits of the flour moth as follows:

"Their migratory habits, when full-fed, were very extraordinary; nothing seemed to keep them within bounds. I had a colony of some thousands in my house, in order to make experiments how to exterminate them; but I found that my breeding-cages, with the finest meshed wire, were useless to restrain them. I then placed them under a large glass shade on a polished surface with no perceptible outlet; but it was no use; the corners and ceiling of my room were within a week studded with their cocoons, and every day specimens of the larvæ were discovered in different parts of the house, from top to bottom; in fact, they increased and wandered to such an alarming extent that I had to give up keeping them."

In the same paper, speaking of the creatures in the warehouse where he made his observations, Mr. Klein says:

"When full-fed the larvæ made their way to the surface, and could be seen in myriads crawling along the floor and up the walls of the warehouse, till they reached the angle where the roof met the walls. There they spun compact silken cocoons, in which they turned to the pupa state."

HISTORY OF THE CALIFORNIA OUTBREAK.

In March, 1892, the president of one the largest milling firms on the Pacific coast invited me to visit one of his mills which, he said, was literally overrun with worms and moths. I inspected the mill the latter part of March, and procured a large number of the moths and larvæ which were responsible for the annoyance. I recognized the insect as the Mediterranean flour moth, and gave the proprietor the necessary warning; but to make sure that my determination was correct I sent specimens of both larva and adult to Prof. J. H. Comstock, of Cornell University, Ithaca, New York, for identification, and at the same time forwarded specimens to Dr. C. V. Riley, United State Entomologist, at Washington, D. C., for comparison with those in the National Museum. The material sent to Prof. Comstock was referred to Mr. M. V. Slingerland, Entomologist to the Cornell University Experiment Station, who replied that there was no doubt about the insects' being that terrible pest, the Mediterranean flour moth. In the absence of Dr. Riley from Washington, my letter was acknowledged by Mr. L. O. Howard, Acting Entomologist, who wrote in reply that my determination was unquestionably correct, further stating that the Department had received no prior information regarding the occurrence of this species on the Pacific coast.

I made frequent visits to the mill during the summer, and each time found the insect more abundant than on my previous examination. After considerable correspondence with the the proprietor, who had become greatly alarmed, I deemed it advisable to send out an emergency circular to various papers on the Pacific coast, in which due warning should be given to millers and dealers of the presence of this formidable enemy. Accordingly, December 1, 1892, I sent out from the Department of Entomology, Leland Stanford, Jr., University, Palo Alto, California, the following circular, which is the first authentic record of the presence of this pest in mills in the United States:

"Notes on the Mediterranean Flour Moth, *Ephestia kuehniella* Zeller.

(*Emergency Circular.*)

"This moth was first found in a flouring-mill in Germany during 1877, and was brought to the attention of Prof. Kuehn, of the Agricultural Institute of the University of Halle, who sent specimens to Prof. Zeller, of Gruenhof, for determination. The insect proved to be new to science, and was described and named *kuehniella* by Professor Zeller, in honor of Dr. Kuehn.

"The moth was little known until 1884 and 1885, when it appeared in some mills in Belgium and did much damage. Several articles appeared in English periodicals in 1887, concerning its ravages in Europe. It caused a great deal of trouble, and in many instances mills were closed. Very little was known about the pest in this country until 1889, when it appeared in Ontario, Canada. Much damage was done; mills were closed, and in one case the loss was estimated at one thousand pounds.

"The fact that such an unwelcome pest has established itself on the Pacific coast is to be regretted. The announcement that it is in our midst should be a signal of alarm to every miller and grain dealer in this region. Notwithstanding its comparatively recent appearance, it has caused much trouble to millers and flour dealers. Every possible means should be taken to eradicate this ravenous pest from our midst. Not only are our mills in danger, but our commerce is at stake, and public health imperiled."

After the publication of this note, I received many letters of inquiry from various parts of the country regarding this pest. I pushed my experimental work in the laboratory, and made good my opportunity of studying this creature in the mill. I endeavored to trace it to its original source, but the more material and facts I gathered on this point, the more complicated the matter became, and I finally concluded it was unsafe to assume that the moth came at any stated time from any given locality.

My first correspondent, on whose premises the moth was first discovered, has given me much valuable information on this subject, and if all millers on the Pacific coast had taken as firm a stand, and fought as persistently as he has for the past three years, the Mediterranean flour moth would not now be so widely distributed. May 24, 1892, he wrote me as follows: "I desire to say that you are correct regarding the moth, and I know that it is a great pest. We have endeavored to exterminate it, and have succeeded in keeping it in check somewhat by constant sweeping and cleaning, and by burning sulphur in the building; but we must now adopt some other means, as it seems to be gaining during this warm weather."

I visited the mill again June 4, 1892, making a thorough inspection, and found a frightful state of affairs. Only a few moths were seen in the basement, but on the other floors I found a very different state of things. In some parts the moths were found upon every piece of machinery and apparatus, and could be seen in great numbers upon the sacks in which large quantities of flour, meal, and grain were stored. Hundreds were clinging to the sides of the mill and about the windows. An occasional moth would take wing when disturbed, but as a rule they were quiet. They were even in the dark chambers of the reels. The larvæ were found in every crack and angle about the machines and wood-work, around bolt heads, in nail holes, and in every crevice where masses of flour had collected. They were particularly abundant in the spouts and elevator legs. I scooped down a handful of the dust that had accumulated in one of the spouts, and upon careful examination found thirty-five larvæ, varying from one eighth to one half inch in length. All the spouts and elevators carrying the more glutinous cereals were in a similar condition. The larvæ were also seen on piles of boxes containing breakfast foods. In fact, in the most isolated places I could find eggs, larvæ, pupæ, and adults.

I made frequent visits to the infested mills during the summer of 1893, and each time found the insect on the increase, and spreading from mill to mill. In April, 1894, I wrote the manager of the mill where I made my first observations, inquiring about the present condition of the place, as compared with one year ago, and received the following reply: "Following up my previous letter to you regarding the flour moth, and in answer to your specific questions in the letter just received from you, I would state that our mill is still infested to some extent, and we are still fighting it, keeping one man constantly employed for that purpose. The condition of the mill, however, as compared with a year ago, is very much improved. We have the pest so in subjection that we are really not suffering any inconvenience from it, nor any loss, with the exception of the wages of the man employed to fight it, and the cost of the material used in the warfare, which is immaterial." During the same month I made a tour of inspection to the worst-infested mills in the State and found that the moth had generally a firmer foothold, and was more troublesome, than the year previous. In answer to a query of August 16, 1895, the president of the firm in whose mill I made my first observations, says: "The flour moth is still with us. It is hardly equal to death, but discoun's taxes in the inconvenience it gives us. The outlook, as compared with a year ago, is about the same as regards the probability of becoming entirely rid of it; but it affords me great pleasure to tell you that I have it in subjection, and that it is not now injuring us nearly so much as formerly." As regards the present distribution of the pest, he says in the same letter: "The insect is increasing in this State. I believe that every mill in California, and in all probability every mill on the Pacific coast, unless it may be some very new mill, is infested by these moths. One of the newest mills in this State, which is now shut down, was more afflicted with these moths than any other mill we have with us. They were so numerous they choked up every spout and elevator, and before the mill had run six months it was necessary to shut down and employ a force of men to take down all the spouts and elevators and clear away the accumulations from them."

My recent discovery of a hymenopterous parasite of the larva, *Bracon hebetor* Say, gives encouragement that the pest may be at least somewhat checked by this little insect. This is the first reported case of parasitism of this insect in this country, and is treated in detail on a subsequent page. Judging from the wide distribution of the flour moth on the Pacific coast, it is safe to predict that the worst has not yet been recorded. It is only by the most persistent and energetic fighting that the pest can be kept in check in any locality; but in California the climate is so equable and so mild that the propagation of the species goes on continuously, and I am in doubt if it ever can be entirely eradicated there. Here is what one of my correspondents says on the subject: "I think I see in this little insect a very serious pest, and that it will be only a question of time when it will be impossible to obtain a barrel of flour that does not contain either the eggs or larvæ of this insect. This would not, however, militate so much against the manufacture of flour as it would against cereals or breakfast foods, or meals, as they are called in millers' parlance. The moth cannot live very long in a sack of flour, owing to its being so densely packed that there is no room for it to move about, and it thus soon dies; but in coarse meals and coarser grain, the moth and larva can move, spin their web, lay their eggs, and multiply; and this I fear will eventually destroy the popularity of breakfast foods, and ruin to a great extent a large trade that has been built up in this country." Millers throughout California have become very much alarmed, and agree with my correspondent, that if something, either natural or artificial, does not check this advancing enemy very soon, the successful operation of large mills will be seriously, if not permanently, injured.

DISCOVERY IN NEW YORK STATE.

In response to my article on the flour moth in the March (1895) number of the "American Miller," I received several interesting letters pertaining to the same subject. One of these revealed a new locality for the pest; the first positive record of its appearance in mills in the United States east of the Rocky Mountains. The letter, dated March 10, 1895, came from the head miller (name and the exact locality omitted by request) of a firm in southwestern New York, and reads as follows:

"Your article which appeared in the 'American Miller' of this month has no doubt been read with a great deal of interest. Of course it can only be appreciated by those who have been afflicted with the flour moth in their mills. I have had charge of some of the best and largest mills in this country, and have never had any trouble with this insect until about a year ago, at which time it took possession of the entire plant in about two weeks' time. I was forced to shut down and take out elevator spouts. The covers were removed from the spouts, and the birds' nests, as we call them, were taken out by the bushel. I would not have believed it had any one informed me, but such was actually the case. I have been a contributor to the milling press now and then, but have not dared to say anything about it on account of being scored by those who have been fortunate enough to escape their presence. I have tried everything to get rid of them, and I think I have succeeded fairly well by using metal spouts throughout the mill."

Upon receipt of this interesting communication, I immediately wrote the miller asking for samples of the material containing the larvæ, and March 20 I received two packages of flour literally filled with the worms, pupæ, and several dead adult moths. The material was placed in a breeding-cage, and the following day (March 21) three adult females emerged, leaving no doubt about the identity of the species. Two more females emerged the 25th; and the first male appeared April 10. With this material I conducted a series of experiments, mentioned later in this paper. The letter accompanying this material is of general interest, and I quote it in full:

"Your favor of the 13th instant is received and noted. I mail you two samples of the webs, as per request, one taken from an elevator leg, and the other from a hopper in a porcelain roller mill, grinding fine purified middlings. I will answer your question as to how they originated in this mill, as near as I can. This mill has been run by the [————] Milling Company for years on a system as nearly perfect as any mill can be run. About eighteen months ago this firm surrendered to the First National Bank of this city, and one of the stockholders became office manager. This gentleman, not being acquainted with the art of manufacturing flour, attempted to cut down expenses. He looked upon the sweeper in a mill as a sort of luxury and dispensed with his services. The mill run night and day and soon became filthy. In about four months' time the moths made their appearance; in fact they got so bad the head miller was forced to resign. I was then engaged, by correspondence, for one year. Had I known the condition the mill was in at that time, I should not have accepted; but, as it is, I have done the best I could. I have succeeded fairly well in getting rid of the pest, and I expect to drive them out entirely."

The remainder of this interesting letter is quoted under the heads of remedies and distribution.

I made the first public announcement of this pest in New York, in a short article in the "American Miller" for May, and special editorial mention of it was made in the same issue, warning millers to be on their guard in that and adjoining states.

I made an especial effort to account for the presence of the flour-moth pest in this mill; but, after a large amount of correspondence, I only ascertained that it had been established for some years in mills at several places in southwestern New York, and, possibly, in parts of Pennsylvania. Some mills in this region were forced to shut down and clean out spouts and elevators nearly two years before the pest came to my attention. The infested district in New York is inland, and to say that the moth came originally from Canada, or from any other specified source, would be pure assumption. The moth is still present in New York; but the head miller who first made known its presence to me assures me, in a letter dated September 14, 1895, that it is not nearly so abundant in his mill as formerly, and that he has it under control.

NEW OUTBREAK IN CANADA.

It will be remembered that the Mediterranean flour moth appeared in destructive numbers in Ontario, Canada, in the year 1889, and after encountering a determined and energetic fight, practically disappeared, little or nothing having been heard of it since in that region. In the November (1895) number of the "American Miller" I recorded its occurrence in the Province of Quebec, Canada, and gave other notes concerning it. My attention was called to this outbreak by Mr. Edward R. Taylor, manufacturing chemist, Cleveland, Ohio, who wrote me September 23, 1895, as follows: "I take the liberty to forward you a letter and sample of flour infested with what appears to me to suit the description of the Mediterranean flour moth. If you will kindly examine the material and report to the party concerned it will be greatly appreciated." The letter was from a Canadian miller, dated September 19, 1895, and read as follows: "I mail you to-day a sample of flour containing a little pest that has appeared in our mill this year for the first time, and is consequently a stranger to me. You will find in the sample several small flies, with their young in the mat enclosed. They are to be found in great quantities in our spouts, in every conceivable corner, and so abundant in purifiers and bolts that it is becoming a serious matter. Any information you can give me, publicly or privately, will be thankfully received."

A careful examination of the material left no doubt as to the species' being *Ephestia kuehniella.* In my reply I asked for additional information regarding the pest, and for a fresh lot of material, as the sample sent was in bad condition when received, having been crushed during transit. I received the following answer, dated October 2: "Replying to your favor of the 26th ult., would say that the pest came into our mill from a neighboring mill during the past summer. We have made no particular attempt to exterminate it. Our mill is a new one, put in only a year ago, and consequently the moth is a new thing with us; but we learn that it was in the neighborhood last year. With thanks for your kind attention we will await the 'American Miller' for further particulars." The sample of infested flour accompanying this letter was placed in a breeding-cage, from which I took two adult females October 15. The specimens did not vary in any particular from typical specimens from California and New York. As to the source of this infestation I have nothing to say. The whole subject of the distribution of this pest is in such an unsettled state that I will not venture to give an explanation of its origin in any given locality.

NATURAL ENEMIES.

In the struggle for existence the flour moth is not entirely free from the attacks of natural enemies, but has many pronounced advantages in the fact that it is entirely concealed in silken tunnels during its larval or feeding state. There are two weak points, however, in its life history; namely, the quiescent or pupal state, and the period immediately after the larva has reached maturity, when its migratory instincts are so strong that it will expose its delicate body for several hours as it crawls about hunting a suitable place for pupation. Nature has taken advantage of these vulnerable points, but, on the whole, interposes but feeble checks on the multiplication of the species.

The reducing agents of the flour moth fall naturally under two heads, predaceous enemies and parasitic enemies, the former including insects, birds, and mammals; and the latter, insects alone. Such data as we have are presented here chiefly as an indication of the practical inefficiency of the natural enemies of this species.

Birds.—Mr. Sidney T. Klein delivered a colony of the larvæ of the flour moth, which he had been keeping in his room for experimental purposes, over to the tender mercies of about fifty game and Plymouth-rock hens kept in his garden, and the greediness with which these larvæ were eaten by the fowls suggested a ready means for the extermination of myriads of those in the warehouse where he had been making observations. Mr. Klein says: "A great number of hens was therefore requisitioned from the neighborhood in the east end, and it was encouraging to see the enormous quantities consumed. But the hens began to flag after ten minutes of gorging, and, although they were kept in the warehouse for several weeks, the insects still continued to increase and spread to other granaries." An outbreak of this pest very rarely occurs where chickens could be utilized for its destruction, and they are therefore of little practical value in this connection.

Mammals.—I have here to relate a curious instance where a common house mouse, *Mus musculus*, devoured several hundred pupæ of the flour moth in one evening. April 11, 1895, I removed a male and a female flour moth, still pairing, from a stock cage, and placed them in a separate cage in order to obtain the eggs for experimental purposes. The eggs were laid and hatched in due season, the first young appearing April 21, and the larvæ were supplied with an abundance of wheat flour and oatmeal for food. The larvæ matured and were all pupated by June 5, the brown chrysalids being plainly seen through the sides of the glass cage. By actual count there were two hundred and fifty-four pupæ in the cage at this time. A mouse discovered this cage sometime during the night of June 12, cut through the Swiss muslin that covered it, and devoured every pupa within. Little or none of the flour and meal in the cage had been eaten. Of course, millers and dealers can turn mice to no good account as enemies of the flour moth, and this instance is introduced simply as a record of the evident relish of one mouse for insect pupæ.

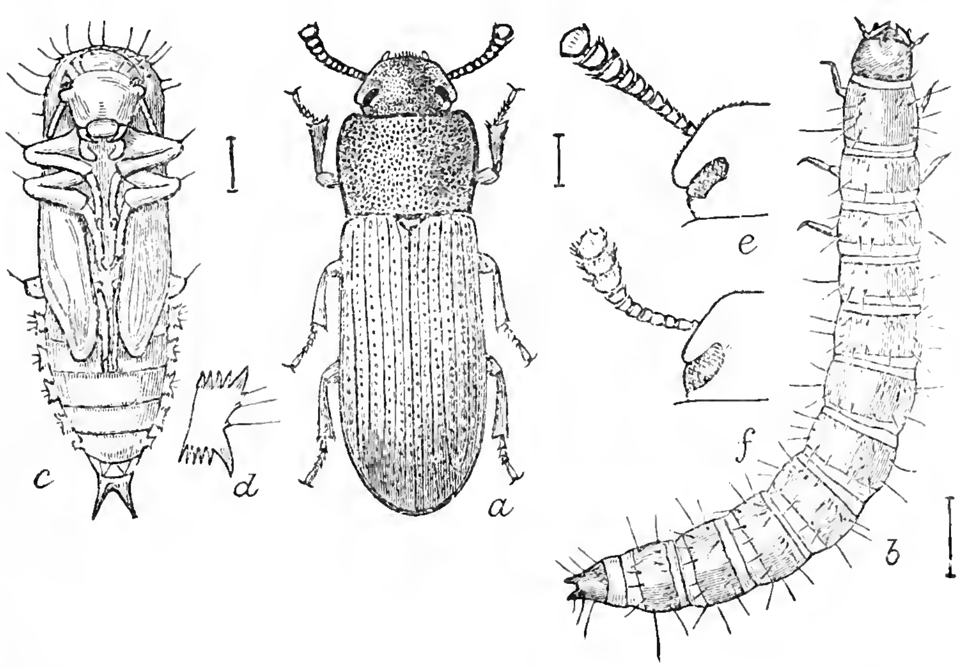

FIG. 5.—*Tribolium confusum*; *a*, adult beetle; *b*, larva; *c*, pupa,—all enlarged; *d*, lateral lobe of abdomen of pupa; *e*, head of beetle. showing antenna; *f*, same of *T. ferrugineum*,—all greatly enlarged. (After Chittenden.)

Predaceous Insects.—Those insects popularly known as "flour weevils" are foremost in this group. They are known to science as *Tribolium ferrugineum** and *T. confusum*. The two species are so closely related that they can with difficulty be separated, and, to the ordinary observer, they are one and the same thing. Their habits are similiar, and the injuries occasioned by them far outnumber those of any other insect that attacks grains and farinaceous foods. Both species are cosmopolitan, and have a wide geographical distribution.

* In speaking of the flour moth larvæ Professor Zeller says: "Simultaneously with these larvæ I received the little beetle *Tribolium ferrugineum*, which multiplied so rapidly that during the summer I sometimes found large masses of its yellowish larvæ. I eagerly destroyed them, fearing they would, at least, be disadvantageous to the larvæ and pupæ of the flour moth. Now, it seems to me that this beetle was unjustly held in suspicion by me, and that it and its larvæ, at most, would help to devour the moths reared for propagation, and dying soon after mating." From this it appears that Prof. Zeller did not observe the weevil feeding upon the larvæ or pupæ of the flour moth. In the same paragraph, however, he says: "I rather suspicion the Ephestia larvæ of devouring little by little, not only their dead parents, but also the pupæ which have fallen out of the web." I have myself seen the flour-moth larvæ attack and devour pupæ of their own kind in a breeding-cage where the pupæ had been uncovered.

They have long been known to infest meal, flour, grain, and vegetable stores in Europe, and in the past few years have become very troublesome in this country, occasioning considerable alarm among millers, flour and feed dealers, grocers, and dealers in patent foods. It is not an uncommon pest in our museum collections, feeding on the dead bodies of insects. The adult insects are small, flat, reddish-brown beetles, about three sixteenths of an inch in length. Our most common species, *T. confusum*, is represented in its different stages in Fig. 5 (p. 39). The eggs are deposited in the flour, from which the young hatch a little later. There are four or five broods during the year. They are offensive creatures, and impart a disagreeable odor to the infested material. Their carnivorous habits, however, make some amends for the mischief they do. I have frequently seen the adults of both weevils preying upon the larvæ and pupæ of the flour moth in mills in California. In one reel, where a great number of the flour-moth larvæ had pupated, it was rather difficult to find a single cocoon which did not contain an adult of either *confusum* or *ferrugineum*, the former species being, however, most abundant. The flour-moth chrysalids, in most cases, had been completely devoured.

August 18, 1895, I placed a hundred adult beetles of *confusum*, received August 16 in flour from Toledo, Ohio, in a breeding-cage in which several hundred larvæ of the flour moth had just pupated, and left them undisturbed for several days. August 26, I made a careful examination and found that the weevils had penetrated two thirds of the cocoons and destroyed the chrysalids within them. August 30, two flour moths emerged from this cage, but no others issued at any time later. There was an abundance of wheat flour and corn meal in the cage, which fact alone would seem to suggest that the weevil prefers insect food when it is available. These weevils were left in the cage undisturbed, where they have been breeding continuously ever since, and there are now in the cage thousands of adults and larvæ.

One enthusiastic miller in San Francisco, California, who observed the flour weevil feeding upon the larva of the flour moth, made artificial breeding beds for the former and distributed them about his mill in the hope of reducing the flour moth, which was everywhere present in his mill. August 23, 1895, he wrote me the following letter on this subject: "I had hopes of some assistance from the little weevil, having observed them feasting on the larvæ of the flour moth. I cultivated colonies of them and distributed them through the mill, and watched them very closely for some weeks. I found that while they did attack the larvæ to some extent, it was still not enough to be of any particular benefit. The little beetles are themselves a pest, as they get into the meals and flour and make trouble there, so I have abandoned any hope in that direction."

I have seen the notorious cadelle (*Tenebrioides mauritanica*), known sometimes as the "bolting-cloth beetle" in California, attacking both the larva and pupa of the flour moth and devouring both the larva and adult of the flour weevil, *T. confusum*, in my breeding cages. I have also seen *Gnathocerus cornutus*, another mill pest, attack and devour the flour-moth larvæ in mills in California.

Parasitic Insects.—The larva of the flour moth is attacked by several species of very small hymenopterous parasites. They are delicate wasp-like creatures, which take advantage of the full-grown larva of the flour moth during its migratory period just prior to its pupation. While the delicate larva is thus exposed the winged parasite lays her eggs, usually upon its body. In one instance at least, that of *Bracon hebetor* Say*, the parent insect paralyzes the larva, reducing it to a helpless condition before the eggs are deposited.

The first true parasite of the flour-moth observed, *Bracon brevicornis* Wesm., was discovered by Mr. Sidney T. Klein in August, 1887, in a London warehouse. He describes the attack as follows: "I held an inspection in August, and brought away several of the full fed larvæ for examination, as I noted some irregular markings which had not been noticed before. These larvæ seemed to pupate quite regularly, and I did not suspect the state of the case until I went down again at the beginning of September. No sooner had I entered the warehouse than I noticed a most extraordinary change in the appearance of the large piles of flour. On closer examination I found this appearance was caused by enormous numbers of a small black fly * * *; and, upon examining several of the larvæ, the majority of which had markings on their backs, the startling fact was established that nature had come to the rescue and provided a remedy herself. It is very rarely that such a striking example of nature's wonderful counterbalancing powers is discovered."

Mr. Wm. H. Ashmead, of Washington, D. C., who is our best authority on this group, informs me that *Bracon brevicornis* is not found in North America so far as he knows.

Specimens of *Chremylus rubiginosus* were bred from *Ephestia kuehniella* and sent to Mr. J. B. Bridgman, of Norwich, England, who records the fact in a communication to the editors of "Insect Life" (Vol. II., p. 260). In a letter from Mr. Ashmead, dated September 21, 1895, he says: "I know this species only by European specimens. It is not yet recorded from North America."

The present economic relationship of *Bracon hebetor* Say to the flour moth was discovered by me September 2, 1895. The insect was first described by Thomas Say in February, 1835,† and is therefore an old-time species. Mr. Ashmead, who kindly determined it for me, says: "I have seen specimens from California, Indiana, Ohio, Illinois, District of Columbia, Virginia, New York, Massachusetts, and other New England States. It is therefore a widely distributed species. It comes very close to my *Bracon gelechiæ*, reared by yourself from *Canarsia hammondi*, in color and general facies, but differs in sculpture and antennal characters."

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* Belongs to Mr. Ashmead's new subgenus *Habrobracon*.

Bost. Jour. Nat. Hist., Vol. 1, 1835, p. 252.

I bred another specimen, a male, from the same lot of flour-moth larvæ, which, although certainly different from typical males of *Bracon hebetor*, is probably only a small variety of this species. Mr. Ashmead characterizes it as follows: "It differs markedly in several particulars—number of joints in antennæ, its more elongated shape, much smaller size, and in color; but until the opposite sex is bred, it would be better to consider it only as a variety of *hebetor*." This little braconid has been bred from the Indian meal moth, *Plodia interpunctella*, in Massachusetts. I have reason to believe that we may expect some good results from it in this country. Out of several hundred flour-moth larvæ sent me by the California miller, only one moth emerged, all the others having been destroyed by the little parasites, of which I removed twenty-seven specimens from my breeding-cage. It is surprising how easily these little creatures can be colonized. It is only necessary to collect a quantity of the webbed flour containing the flour-moth larvæ and place it in a breeding-cage, into which the parasites are afterward introduced. Here they multiply rapidly, and can be liberated at will in the worst-infested parts of the mill. I have suggested this expedient to the president of the milling firm from whom I received the larvæ.

I will now give, somewhat in detail, notes of my own observations on *Bracon hebetor*. When I discovered this little parasite, I noticed that several of the flour-moth larvæ were lying in the bottom of the cage in a helpless condition, although presenting the fresh and plump appearance characteristic of living larvæ. Upon examination I found that they were not dead, but in a state of lethargy. Two larvæ in this condition were removed from the cage and placed in a glass tube, where they remained perfectly motionless, but still gave on the fifth day evident signs of life by a slight movement of the thoracic segments when touched with a needle point. This movement was not noticeable on the sixth day, and the larvæ were dried up and shriveled two days later. It is quite probable that this paralysis is caused by the adult parasite, but in what way has not yet been worked out satisfactorily. I have now several experiments in progress to determine this point if possible. I have observed the same paralytic state in larvæ of *Canarsia hammondi*, and in nearly every case have found the eggs of *Bracon gelechiæ* either on the body of the larvæ or on the silk or web immediately over them. In this latter case it is very important that the larvæ should not move after the eggs of the parasite have been deposited, as the little grubs hatching from them are legless, and could not crawl far in search of food. I am of the opinion that *B. hebetor* deposits its eggs in much the same way. I have not seen the eggs of this species, but have found grubs just hatched attached to the external surface of the flour-moth larvæ. In one instance, September 18, 1895, I removed a larva from a cage with five grubs, just emerged, feeding upon it, two of which were removed and placed in alcohol, and the others were left for development. The following morning, at 8 o'clock, they had left the larva and were forming cocoons on the side of the tube. The cocoons were completed by 8 o'clock, September 20, and were whitish in color. The fully developed chrysalids could be plainly seen by the 23d, in which condition they remained until October 7, when the adult parasites emerged. From this one observation it appears that the grubs reach maturity in one or two days; that one day is required for the construction of the cocoon; and that a little over two weeks is passed in the pupa stage, making about three weeks for the complete life cycle of the parasite. It will be remembered that about nine weeks are required for the complete evolution of the flour moth, so that there would be three generations of the parasite during a like period.

PREVENTIVE AND REMEDIAL MEASURES AND MECHANICAL DEVICES.

It is now a well-known fact that this moth is carried from mill to mill in the greater number of cases through carelessness. Millers who have never been troubled with insect pests think there is nothing to fear, and carelessly permit all sorts of material, such as empty bags, barrels, boxes, and second-hand machinery, to enter their premises without even suspecting the presence of their worst enemy. The indifference displayed by most millers who have been fortunate enough to escape the ravages of insect pests in their mills, is truly lamentable. All preventive measures are ignored, the mills are often dirty through neglect, and unconcern prevails. These very people, sooner or later, will suffer severe mental anxiety and heavy financial loss for their negligence. Other firms neglect their mills simply because they are new, thinking they have nothing to fear from outside foes. Some of the worst flour-moth outbreaks recorded in this country have occurred in newly constructed mills. One of the newest mills in California was obliged to shut down before it had run six months, and employed a force of men to take down all spouts and elevators and clean out the accumulations from them. The Canadian outbreak at Valleyfield, Quebec, is another instance. The mill was constructed about a year ago, and has been obliged to shut down several times during the past season in order to clean out the webs from spouts and elevators. When a mill is clean and new it would certainly be good policy on the part of the owners to keep it fresh and clean. In this day of common insect pests, a sweeper or duster is indispensable to the successful operation of a mill. He should be thoroughly acquainted with all insects injurious to mills, mill products, and stored grain, and competent to apply such measures as may be requisite for their arrest and destruction. He should be responsible for the inspection of all incoming material, of whatever sort, where there is the slightest question as to its freedom from insect pests.

Where the flour moth has established itself in a mill, it can be kept in subjection only by the most persistent and energetic fighting. The standard remedies are steam, sulphur, and bisulphide of carbon, all of which are soon to be considered in detail. I shall discuss here only such remedial measures as have been used successfully by milling firms, including suggestions warranted by my own experimental work.

Cleanliness.—The only safeguard against insect pests in mills is scrupulous cleanliness. This can be attained by constant sweeping and dusting; but a much more effective method has been perfected and used by one of my San Francisco correspondents, whose procedure is as follows: "I am now employing," he writes, "a scheme for cleaning our mill which I find the most efficacious, taking it all around, of anything I have tried. I have run a half-inch pipe under each ceiling of every story in the mill, and every twenty-five feet I have a steam-cock, so that I can attach a steam hose, on which I use a nozzle (the same as that used on any garden hose). With this arrangement I thoroughly steam all the spouts, corners, garners, walls, posts, in fact every part of the mill. It is the best cleaning apparatus for a mill that I have seen. One man in one day with this hose will sweep the mill cleaner of dust, dirt, and other accumulations, than twenty men could do with broom and brush. In fact it is impossible to clean out dust with broom and brush as well as it can be done with steam. I recommend this scheme to all those with whom I talk, and you can safely recommend it to all your correspondents as being an excellent thing. There is no other apparatus that will cleanse a mill so thoroughly." This is by far the most practical method known to me, and I commend these steam pipes to millers as a most necessary part of the equipment of a mill. No new mill should be contemplated without incorporating the "steam sweeper" in its plans and specifications. Such an equipment will pay for itself in a short time, and a clean well-kept mill certainly commends itself to public favor. The cautions to be observed when steam is used in mills are discussed on p. 54. Great care should be taken not to allow loose material, empty bags, boxes, and the like, to accumulate about a mill. All such rubbish should be burned if it has no commercial value.

Fumigation Box.—Every well-equipped mill should have a tight wooden box, large enough to hold all the bags, boxes, or barrels that usually come and go from the mill, or are in circulation among local customers. Such material should be thoroughly steamed, or subjected to the fumes of sulphur or bisulphide of carbon, before being permitted to re-enter the mill. Any second-hand machinery that may be bought should be treated in the same manner. Instances where the flour moth and other insect pests have been carelessly introduced on old bags and second-hand machinery have already been given.

Metal Spouts.—Any substitution of one piece of apparatus for another that will in any way make it more difficult for insects to find lodgement in a mill, will certainly be productive of good and lessen the chances of infestation. It is a well-known fact that the flour moth finds spouts and elevator legs its most favorable quarters. The wooden spouts are so arranged that the larvæ have no difficulty whatever in clinging to them, and consequently great quantities of flour are matted together and cause the trouble

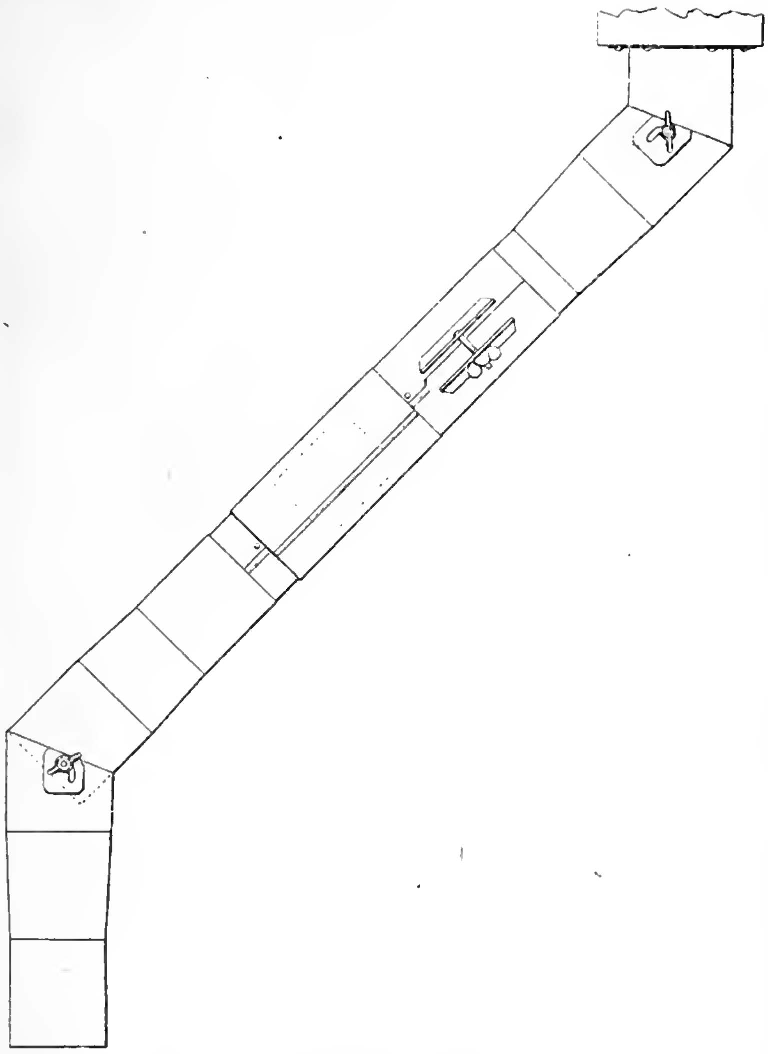

FIG. 6—Adjustable metal spout.

in such places. This liability may be removed by the substitution of metal for wooden spouts. The metal spout was first used for this purpose by the inventor, Mr. L. C. Schroeder, of Olean, New York, and is protected by a patent. These spouts are perfectly smooth and there is no chance for an insect to find lodgement within them. The inventor claims that they can be made for less money than the lumber costs for wooden ones, and that a millwright is not needed to put them in position. (See Fig. 6.) I might say in this connection that Mr. Schroeder has also applied for a patent for a metal elevator leg, which, when on the market, will afford another useful piece of apparatus for preventing the establishment of injurious insects in these parts of a mill.

Where metal spouts have been resorted to in mills overrun with this scourge, the results have been very satisfactory. In March, 1895, a New York miller wrote me the following letter on this subject: "I have discontinued the use of wooden spouts and have substituted metal ones. Since I adopted this spout I have had no trouble with the moth in the plant, but it has drifted from here to the flour department, and seems to be most abundant in the purifiers and rollers. I am now removing all the wooden spouts as fast as I can in the flour department, and I hope to be able to get rid of the pest before warm weather comes on."

This letter was followed by another communication from the same miller, dated August 14, which I quote in full, and which needs no comment: "The Mediterranean flour moth is a thing of the past, or nearly so, in our mill. When I wrote you last [March 17] this mill was alive with them; but I have rooted them out by degrees. I was confident I could do it. As I said before, they shifted about from the meal department to the buckwheat department and then to the flour department, all three plants being located under one and the same roof. The latter part of May I shut down four days for the sole purpose of cleaning out this pest. I ran down the stock as close as possible and then had the mill swept from top to bottom. I then took down all wooden spouts and replaced them with metal spouts. I have metal spouts here which were put in nearly twelve months ago in our meal department, and during that time not a moth has been seen in them; in fact, they cannot locate in them, for they are perfectly round and smooth inside. It is in the corners of a wooden spout that the worms locate and spin their webs. It would be a hard matter for me to find a sample of stock in this mill, at present, that contains either the worms or moths."

Attachment of Brushes to Belts.—The fact that the larvæ of the flour moth cause most trouble in spouts and elevator legs has suggested the attachment of several brushes to the belts, so arranged that they constantly clean the sides and corners of the spouts and the elevator legs. Where it is necessary to retain the wooden spouts in an infested mill, this device is highly recommended and should be kept in constant use. It has been successful in France, and one of my California correspondents who is using the brushes says: "Our spouts were continually choking up, so that we had to employ one or two extra men in operating the mill in order to take care of the choke-ups that occurred. Now we have no difficulty whatever. The elevators and spouts are entirely clean, and we have no trouble with worms in our mill; in fact, we hardly notice the existence of the pest at all, but we realize that we must keep up a constant warfare on them or they will immediately increase to such an extent that we shall be in as great trouble as before."

The "American Miller" for December, 1895, contains a communication from a practical miller bearing directly upon this subject, and I quote it here in full:

"*Editor American Miller:* Millers are often troubled with elevators sweating and dust settling in them, which becomes musty and moldy. More or less of this is bolted into flour, and as a result musty flour comes back to the mill. I have designed an elevator brush to prevent this trouble, a drawing of which is presented in the accompanying illustration. [See Fig. 7.]

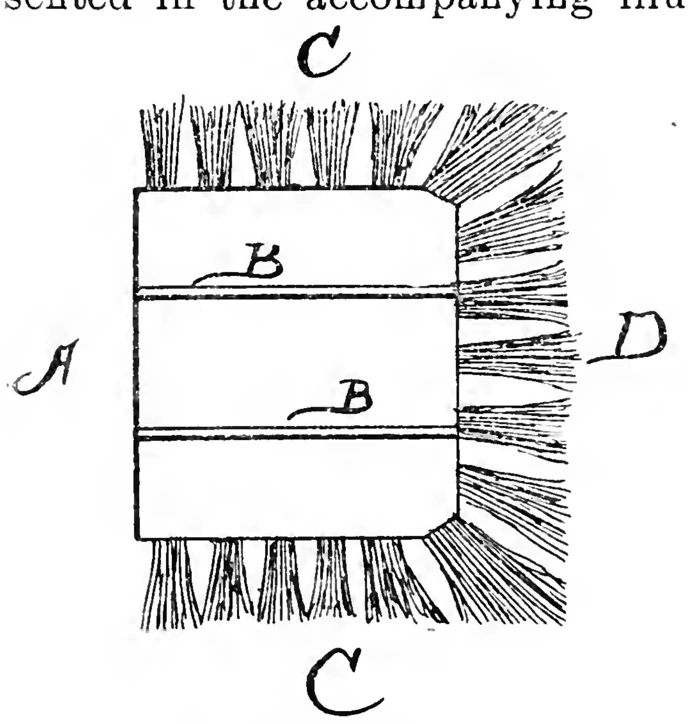

Fig. 7.—Elevator Brush.

"To make the brush take a piece of $1\frac{1}{2}$-inch plank of the same dimensions as the elevator cups, and fasten bristles to three sides. The side A is fastened to the elevator belt with flat-headed bolts running through the plank, as shown at B, B, the bolts being $\frac{1}{4}$ or $\frac{3}{8}$ of an inch. The bristles on the sides C, C, should be $\frac{3}{4}$ of an inch long, but those at D should be longer, so that they will give a good brushing to the outer side of the elevator. The brush is easily made, and the miller can make it of any size to fit his elevators."

I will now consider, in the order of their effectiveness, substances which have been used with the most satisfactory results in combating the flour moth. Bisulphide of carbon stands first, followed by steam, sulphur, and steam and sulphur combined.

Bisulphide of Carbon.—The simplest, most effective, and least expensive remedy for all mill pests is bisulphide of carbon, a very inflammable, volatile, foul-smelling liquid, as clear as water. Its vapor is heavier than air, and will penetrate every crack and crevice in a mill or warehouse when used in sufficient quantities. It can be thrown directly upon grain without injuring its edible qualities, and will not affect its vitality in the least. In mills it can be used about the machinery, spouts, and elevators with perfect assurance that the manufactured products will not be damaged. It is a powerful insecticide, the atmosphere produced by its vapors being sure death to insects, as well as to rats and mice. I know of no instance, however, where the slightest deleterious effect has been realized by persons applying it in mills, although they unavoidably inhale some of the fumes.

The amount of liquid to be used depends (1) on the size of the building, (2) on its tightness, and (3) on the magnitude of the attack. Where the building is reasonably tight and but slightly infested, one pound of bisulphide is sufficient for every thousand cubic feet of air space. If it is somewhat open or badly infested the amount should be doubled. When applied to bins containing stored grain, one pound of the liquid to every hundred bushels of grain is commonly used; but if the insects are very abundant the amount of bisulphide should be doubled.

A number of methods for the application of bisulphide of carbon have been suggested and tested, but the most effective manner of applying it in mills consists in simply pouring the liquid into shallow dishes, such as soup plates, or pans, and distributing them about the building. Bits of cotton-waste saturated with the liquid should also be thrust into spouts, elevator legs, machines, and other places where the pests usually congregate in great numbers. Spraying or throwing the liquid broadcast into badly infested corners, on machines, and other pieces of apparatus where the pests are particularly abundant, has been attended with very good results.

Saturday afternoon is the best time for fumigating a mill. After sweeping it from top to bottom, using a "steam sweeper" where it is practicable, all fires about the premises should be extinguished and the mill closed as tightly as possible. The dishes and cotton-waste should be previously distributed, so that there will be no unnecessary delay in the application of the foul-smelling fluid. The distribution of these vessels must of course depend, as already stated, upon the condition of the mill and the severity of the attack. It is best to begin with the lowest story and work up, as the operators can then keep above the settling gas. When the bisulphide has been applied throughout the mill it should be locked and kept closed until the following Monday morning. All windows and doors should then be thrown wide open and the building allowed to air an hour before any fire is started. Where the building is large and a great quantity of bisulphide has been used, it would be wise to observe the extra precaution of stationing a watchman without to prevent any one from entering the building during fumigation.

As a guide to millers who may use this method for exterminating insect pests in mills, I will quote several letters from practical millers who have used bisulphide of carbon successfully. The superintendent of a large Pennsylvania milling company, whose name is withheld by request, under date of July 12, 1895, wrote me the following letter, which is a valuable contribution to this subject, and should be read by every wide-awake miller and grain dealer:

"We have delayed answering your valued favor of May last until we were able to report the result of our efforts to destroy the weevils in our mill. Following in the line of your advice, we ran our stock down and thoroughly renovated our mill from top to bottom, cleaning all reels and purifiers. We then fumigated the whole mill with bisulphide of carbon. We distributed 300 soup plates about half filled with bisulphide through the mill, and saturated balls of cotton with the same material and placed them in all the reels and purifiers. This we did on Saturday night and closed the mill tight and left the weevils to their destruction.

"We opened the mill Monday morning and thoroughly ventilated it before starting. We found that we had destroyed thousands, and in the reels and purifiers we had killed them all. In the course of a few days, however, they began to show up in the cracks in the floors all over the mill, and in dark corners. Two weeks later we repeated the dose of bisulphide in the same manner and obtained about the same results. In the meantime, however, we whitewashed the mill from top to bottom, that is, every place that could be covered, putting on a good heavy coat. We have not destroyed them all by any means; but we have reduced their forces to a very small number. Eternal vigilance is the order of the day.

"We are still fighting them. Our plan is to keep a stock of bisulphide on hand outside of the mill building, as we do not think it advisable to store it in the mill on account of its inflammable nature. Wherever we find a place infested by the weevil we use it freely, taking care to do it when the mill is shut down and closed up tight. We find the best results from the use of bisulphide of carbon can be obtained by spraying it on the floors and infested places. We think when placed in plates it does not evaporate quick enough to produce the death atmosphere required. Before closing let us return our sincere thanks to you for the interest you have taken in the matter, and assure you that we appreciate your valuable advice."

The "American Miller" for July, 1895, contains another interesting and valuable communication on this subject, from Mr. H. J. Laurie, of Norwalk, Ohio, and I quote it here in full:

"As the season is now upon us when a large majority of the flouring-mills of the country are being troubled with insects of various kinds, such as weevils, worms, moths, etc., I thought it might not be out of place to give our experience here with bisulphide of carbon, which we have been using for several seasons with very satisfactory results.

"I have reason to believe that a number of millers have used this remedy with very indifferent results, owing, in my opinion, to the manner in which it was applied. In the first place, the mill should be thoroughly swept (as every mill should be daily), and if there are any broken panes of glass in the windows they should be replaced, the object being to make the mill as tight as possible. Then have a number of shallow tin pans, say, about fifty to every 100 pounds of the compound used. Begin at the top [bottom] of the mill, and place the pans where the insects are the thickest. It is best for two to go together, one placing the pans, the other filling them, using a watering-can or something of the kind having a spout.

"I apply it to the bolting reels and flour garners as follows: I get ready, beforehand, a number of medium-sized bunches of cotton-waste, two for each reel, with a string attached to each. I dip these bunches into the bucket of compound, pressing out with a paddle so they will not drip too much; then throw them under the reel and down on the conveyor, leaving the string on the outside so they can be recovered, then close the doors of the bolting chest tightly. I suspend one or two bunches in like manner in the flour garners and screening bins. In applying it to the wheat bins we level off the grain and place the pans on it filled with the liquid. By applying it in this way to wheat bins and taking proper care to have the bins emptied and swept out occasionally, no one need be troubled with weevils in their grain elevators. There is one thing that we have discovered, and that is that the compound must be reasonably fresh when used. If kept for any great length of time it loses its strength, consequently it should be used as soon as practicable after receiving it, and no more should be ordered than it is intended to use.

"Before commencing the use of bisulphide of carbon this mill was badly infested with weevils and other insects. Now we are nearly free from the pests. I do not say that this remedy will kill every insect in a mill. I do not think there is an insecticide made powerful enough to reach every nook and crevice, such as we have in mills; but we do know that by a judicious use of bisulphide of carbon in warm weather, when the insects are in full force, and by a due regard to cleanliness all over the mill, any mill can be rid of the pests.

"The compound being highly inflammable, there should be no fire or lights used in the mill at the time it is applied. The best time to apply it is Saturday evening, and the mill should be kept closed till Monday morning."

There have been so many exaggerated reports about the nature of this chemical compound that it is necessary to give a few notes regarding it in this place. In this connection I can do no greater service than to quote a letter from Mr. Edward R. Taylor, of Cleveland, Ohio, the leading manufacturer of bisulphide of carbon in this country. It appeared in the "American Miller" for September, 1895, and reads as follows:

"*Editor American Miller:* I have seen a great many very random statements on the subject of the inflammability of bisulphide of carbon. One says, 'Use the same care as with gunpowder.' Another says 'It is a very explosive liquid.' These are both very misleading statements with reference to the properties of bisulphide of carbon. I have quoted the statements, however, in my printed matter for the reason that farmers and many others use the goods, and will be sufficiently startled by such statements to be careful and have no light or fire about.

"Nearly everybody is now familiar with gasoline. The properties of that liquid and bisulphide are practically identical in that both are inflammable but neither of them explosive. The vapor of either of them mixed with air is explosive, but the liquids are not explosive. I have shipped thousands of pounds of bisulphide to millers, elevator operators, and farmers in the last few years, and I have yet to have the first report of any disaster, even of the most trivial character, from a single one of them. Need I say more? My directions are explicit: Do the work Saturday afternoon by daylight. Absolutely have no light or fire of any kind about. Close the mill and leave the bugs to their destruction till Monday morning. Then open doors and windows, and thoroughly ventilate before going to work."

Some of the insurance companies have commenced to feel a little uneasy lest they should suffer loss by fire originating from the use of bisulphide of carbon in mills. The "American Miller" has investigated this subject by sending letters of inquiry to all the more important millers' insurance companies in the United States and Canada, and so far has not learned of a single fire which is known to have been caused by the use of bisulphide of carbon. The properties of the fluid have been fully described repeatedly, and millers have been warned to keep lights and fire away from the vapor, lest an explosion should occur. The fact that it has been used so long without fires being traceable to it, gives strength to the opinion that millers, out of consideration for their own lives, have heeded the warning and have been exceedingly careful in applying it. When they become more familiar with its use they may grow careless, but we hope such will not be the case. It should not be stored near the mill, as this increases the fire risk. A break in the can might unexpectedly release fumes which would soon fill the mill.

Bisulphide of carbon is sold at drug stores at from 20 to 30 cents a pound, but can be bought much cheaper at wholesale, directly from the manufacturer. A grade known as "Fuma Bisulphide of Carbon" can be obtained directly from its manufacturer, Mr. Edward R. Taylor, Cleveland, Ohio, in fifty- or hundred-pound cans at ten cents a pound, and is as effective as the ordinary grades on the market. A carefully prepared circular containing full information for its use and the necessary precautions to be heeeded during its application is sent with each order sold.

Sulphur.—From a practical standpoint sulphur ranks next to bisulphide of carbon, as an effective remedial measure, but it must be handled with great care. The burning of sulphur in infested mills has been attended with both good and evil results. The experience of the millers cited below, should be sufficient warning for all those who may resort to this method for the suppression of insect pests. The experience of an English miller, as related by Miss Ormerod in her Fourteenth Report (p. 58), is given in the following paragraph: "But we found that sulphuring has an effect which we did not anticipate or wish. We had standing in the mill when the fumigation was carried on, some eighty or a hundred sacks of flour, and we find to our dismay that the sulphur has penetrated right into these, and acted on the gluten of the flour in such a manner as to apparently break up all soluble albuminoids, and render the dough made from it more like a lot of weak putty than the strong, tough dough our customers require."

In May, 1892, the manager of a San Francisco mill, who tried the burning of sulphur in his mill for the destruction of the flour moth, wrote me as follows: "The fumes of the sulphur acting on the different cereals, destroys certain properties of the grain and flour, rendering both useless for bread-making purposes. On our first application of the sulphur fumes we nearly destroyed about a thousand barrels of flour. This was very discouraging and has since prevented us from applying that gas in so extensive a manner as is necessary to fully exterminate the moths."

Even after this sad experience, the same miller is of the opinion that sulphur is the best remedy for keeping the pest in check when used in the proper manner.

Another California miller, who has had much experience fighting the moth, writes me as follows: "We cannot use sulphur in the mill any more without taking out all the flour and grain that we usually carry in stock. We find that the fumes of sulphur destroy the vitality of the flour by some chemical action rendering the flour worthless for bread-making purposes. They also destroy the value of the wheat for flour-making purposes, as the flour made from fumigated wheat makes no better bread than the fumigated flour."

Other instances of this nature might be given, but these will suffice. In preparing to sulphur a mill the stock should be run down as low as possible, and all flour and wheat removed before the sulphur is ignited. Care should be taken also to see that all windows, doors, and other openings are closed. Various ways have been suggested and tried for burning sulphur. A California miller outlines his method as follows: "Our method of using the fumes of sulphur is to take an iron pot, set the same in a can of water, put in a quantity of sulphur, or pulverized brimstone, pour over it some alcohol and set the same on fire. Then close up everything tight, so that the fumes cannot escape. This will kill every living thing with which the gas comes in contact. We have frequently found dead mice on the floor after having fumigated the place. We use this sulphur in parts of the mill which can be tightly closed so as to prevent the escape of the fumes."

Dr. Bryce, speaking of destroying the flour moth in Canada, says: "This can be done by closing the windows, doors, or other apertures of the building, and, night after night, until all evidences of moths have disappeared, burning sulphur by placing it in shallow pans, upon a number of heated stoves, say, small coal-oil stoves, in different parts of the building and putting a match to it."

The following method is also given by Dr. Bryce:

"To prepare sulphur fumes: Place a metallic dish containing hot ashes on some support in a pan of water, or place in an old pan or other vessel a bed of ashes at least 6 inches deep, and about 15 inches in diameter, and place the sulphur and saltpetre in a slight depression in the centre and ignite. The proper proportions are 3 lbs. of sulphur and 3 oz. of saltpetre per 1,000 cubic feet of air space. All doors, windows, and other openings should be tightly closed before the sulphur and saltpetre are ignited."

There are certain necessary precautions to be carefully observed in burning sulphur in mills, which may be given briefly as follows: (1) Remove all grain, flour, or other manufactured products from the mill; (2) see that all external openings are closed before the sulphur is ignited; (3) have the vessels containing sulphur so arranged and situated, that there will be no danger of fire from that source; and (4) thoroughly air and clean the mill again before resuming work. Particular attention should be given to the cleansing of the machines, especially those used for manufacturing flour and other farinaceous foods, as the sulphur compounds will continue to act on the manufactured products some days after disinfection unless this caution is heeded.

Steam.—Steam has been used in mills for the suppression of insect pests with considerable success. Miss Ormerod suggested the possibility of destroying the larvæ of the flour moth by turning on steam from the boiler—a plan which had been entirely successful in clearing a cheese factory of maggots which had spread to every nook and corner. This method was tried by an English miller at Miss Ormerod's suggestion, and he outlines his method of procedure as follows: "The way I applied the steam was by carrying about forty yards of half-inch piping into the mill from the boilers, and attaching an india-rubber hose to it for the men to work about on the walls, floors, spouts, and machines, blowing the steam into all the crevices and holes. I stopped the mill for a week while this was being done. It has rusted all the shafting, etc., but this is quite a secondary matter as it can soon be cleaned again. After blowing the steam, which took two or three days, I set the men to work to wash the walls (and every other surface that they could without fear of affecting the flour) with paraffine [kerosene]. The inside of the machines I had washed with a strong solution of boiling water and soda."

In Canada the Local Government compelled the miller, on whose premises the pest was first found, to take down all the machinery and apparatus in his mill and subject it to a thorough steaming. The sad experience of this miller is related by himself and is quoted here in full from Dr. Bryce's bulletin (**26**):

"In the meantime we took down our machinery and subjected it to steaming. Every part was thoroughly steamed. The mill was swept down, and subjected to sulphur fumes. The walls, ceilings, etc., were cleaned, and elevator spouts and loose wooden work burnt up. Paper bags and hundreds of dollars' worth of goods were burnt in the furnace, while the other bags, elevator belts, and cups were boiled for hours in a cauldron of water. The machines and all parts that were not destroyed were then burnt by means of a kerosene torch, which flamed and smoked through and around every part of them until we considered we had everything clean and ready for putting together again.

"But on the 19th of September, the Local Government passed an Order in Council compelling us to take more stringent steps, and on the 20th of September, we received an order from Dr. Bryce, which stated that before placing our machinery in position we should subject it to a thorough disinfecting process in a strong room, so arranged that steam under pressure might be drawn or driven into it.

"In compliance with this order we at once constructed a tight steam box 6 feet wide, 6 feet high, and 12 feet long, and attached a steam pipe to it from the boiler. In this box we put every machine, and even our mill stones and iron rollers. This process was very expensive, and took up considerable time, as we were over a week at the process and were delayed in the placing of our machinery. The Board of Health visited us in a body during the time this process was going on, and pronounced it a success. This was all done not only in our own interests, as was pointed out in the letter of the 20th of September from Dr. Bryce, but in the interests of the public health and commerce of the country.

"Having now got in a position to go to work again, after two months' loss of time, and loss of machinery, fixtures, and stock, attended with much expense, we have arranged for remedial measures to prevent the reappearance of the pest or to destroy it if we should ever again be attacked. We have erected a steam stand-pipe with hose or other connection on each flat of the mill building. By shutting up all the doors and windows of each flat and turning on the steam simultaneously to each floor, the whole building can be filled with hot live steam sufficient to kill anything. This will rust all bright parts of the machinery, but to remedy this we intend using oil on them, should we ever be under the necessity of resorting to the measure.

"Another purpose of this steam stand-pipe will be in cold weather to let on sufficient steam to moisten everything and every part of the building at night, and then throw open the windows for the night and let the frost penetrate so as to kill any eggs or insects that may have become lodged in unseen parts.

"By these measures, with plenty of light, thorough cleanliness, a cold mill, and caution in taking in stock and old bags, we hope to keep free of the pest which has occasioned us so much trouble and loss."

One of my California correspondents, who is now using steam for the destruction of this pest, says: "By the use of this system I am now keeping the flour moth in check, but I am compelled to go over the mill, from top to bottom, at least once a week. If I let it go longer than that I observe a decided increase of the moths in the mill and worms in the goods. On the whole, I find this the most efficacious method I have tried since the moths have been with us."

The most satisfactory method for equipping a mill with apparatus for steaming purposes, now known to me, is that described on page 44, and used by a San Francisco miller.

There are several points about this method of destroying insects that should be carefully considered.

1. Any grain, flour, or other manufactured product left in a mill during the steaming process is liable to become damp and seriously injured. All such material should therefore be removed before the steam is turned on.

2. The bright parts of machinery and other apparatus are liable to become rusty if not wiped thoroughly dry immediately after the operation, or oiled before the steam is turned on.

3. The "steam sweeper" or steam introduced by means of a hose and nozzle, is certainly more advantageous than steam intrcduced through other pipes where the entire mill is filled at one time, as in the former case it can be directed into corners, spouts, machines, or other places where the attack is severest, with less liability to the injuries specified under 1 and 2.

4. Steam can be used to best advantage during the summer months, as the windows and doors can be thrown open at this time. In cold weather, or during the winter months, when the mill is tightly closed, the steam on the cloths of the purifiers often causes trouble, the middlings running the wrong way. Steam sweeping, on the whole, is most successful in the summer months, except in California and some of the Southern States where there is a mild and equable temperature.

Steam and Sulphur.—The use of steam and sulphur combined has been attended by very satisfactory results. My California correspondent, after his bitter experience with the sulphur, writes again: "I think that there is no doubt but that the moth can be exterminated from any one mill by sufficiently long-continued applications of sulphur fumes and steam. This, however, necessitates a great expense in moving all the stock out of the mill, and also loss of time that would result in shutting down the mill to make the application. I do not believe that all the eggs, larvæ, pupæ and adults could be destroyed in less than one week's constant application of the gas and steam. This process would leave the mill in such a condition that unless the acid which is deposited by the gas could be neutralized by some agent it would be impossible to make any flour that could be used for bread-making until all the acid deposited should have been absorbed and carried away, which would result in enormous waste of material. I find, however, that the acid could be neutralized to a great extent by ammonia, and this, or some other equally powerful agent, would have to be used before turning the mill on to making flour again after the application of the gas."

In dealing with the Mediterranean flour moth eternal vigilance should be the order of the day, and if the above methods are faithfully employed, I think that we shall, in a few years, hear little or nothing about the insect in the mills of this country.

MISCELLANEOUS EXPEDIENTS.

Many ineffective expedients have been resorted to in the warfare with the flour moth, but they deserve only passing notice, and are mentioned here mainly for the benefit of experimenters.

Kerosene.—We have used this substance for washing walls, apparatus, and the inside of machines, but find it slow and tedious, and I would suggest its use only in extreme cases, where it is necessary to take a machine or other piece of apparatus apart.

Solution of Soda and Water.—A strong solution of soda and water has been used to good advantage for washing the inside of machines, and is very effectual in destroying larvæ when it comes in actual contact with them.

Soap and Lime.—A mixture of soft lye-soap and lime has been used for washing elevators and bolting-reels. This, like the above washes, is used mainly for cleansing the machines, and is of very little value unless the washing is kept up at regular and frequent intervals.

Buhach.—This substance (also called pyrethrum, insect-powder, etc.) was burned in a single mill with slight success. It is not as effective as bisulphide of carbon or sulphur fumes, and is more expensive. Mr. Danysz has given quite a lengthy account of his experimental work with this substance in his paper.

Ammonia.—Ammonia has been tried without success.

Hydrocyanic Gas.—I have some hopes from the use of hydrocyanic gas, but have not carried my experiments far enough to be certain of its safety or of the feasibility of its application in mills.

Corrosive Sublimate.—A solution of this substance has been used in mills for spraying walls, floors, and ceilings, but on account of its poisonous nature I would not recommend it.

Lime.—Very many millers after thoroughly cleaning and then whitewashing their mills have found that the pest was more easily kept in check. If the ceilings and walls of the mill are not tight, I would suggest that a little glue be added to the whitewash before being applied. Various methods have been used for applying this substance. Some paint the ceilings, walls, and floors, using a brush; while others use a pump and sprayer, forcing the lime into every crack and crevice. Ordinary whitewash, as commonly used, rubs off easily and often becomes a source of annoyance. This can be overcome by adding a handful of common salt and about half a teacupful of lard to each gallon of the wash, which should then be thoroughly stirred before being applied. One of my California correspondents, in a letter dated August 27, 1895, says: "When making the whitewash I put in all the sulphuric acid that can be used without burning the pipe through which the wash is sprayed on the walls. I believe this acid is a good thing."

Sulphuric Acid.—A strong solution of sulphuric acid has been used to wash machinery, elevators, and spouts with good results, the acid being afterwards washed off with water.

Tobacco.—The burning of tobacco in mills is not effective on a large scale, but has given fairly good results in small, tight rooms and bins. Tobacco infusion has also been used for washing and cleansing apparatus, but, on the whole, it is not a satisfactory substance for general use.

Flour Paste.—The value of this material is summed up in the following letter from one of my California correspondents: "In answer to your question, 'What led you to try the flour paste experiment? I would state that we use flour paste for putting up packages of small goods. This paste is made, as needed, by one of our workmen, and is composed of flour, water, and vinegar, and is boiled by steam. I pay particular attention, in a general way, to all the work going on in the mill, visiting it every morning and going through every department. On one or two mornings I noticed that during the night the moths had seemed to congregate about this paste, many of them having fallen into it, and as it is of a tenacious nature they could not get away, and had perished. This seemed to be a curious kind of a thing to me and I made some investigation—had some of the paste put out in shallow pans, and I discovered that it had an attraction for the moth. I found, however, that it must be in a certain stage of fermentation in order to be of any value as an exterminator. I then commenced a series of experiments on a large scale, and in a short time had so reduced the number of moths in the mill that I was very much delighted with the result. At the same time I carried on experiments with other materials, the cost of the paste being a considerable item, since it had to be renewed every few days in order to be of any service."

Vinegar and Water.—This experiment was suggested by the one immediately preceding, and is outlined by the same miller in a letter dated August 23, 1895, which I quote in full: "I have tried numerous ways of getting rid of the pest, and, if I remember rightly, when I saw you last I was experimenting with flour paste. My experiments in that direction gave some promise of success, but I eventually abandoned the flour paste for a mixture of vinegar and water—about one fourth vinegar to three fourths water. This seemed to attract them as much as the paste did, and was not nearly so inconvenient, for the pans did not need to be replenished nearly so often as with the paste. The paste seemed to attract them only in a certain stage of its fermentation—after that stage was passed they did not appear to care anything for it. The vinegar, however, attracted them until it had evaporated; but the acid contained in the mixture soon ate the pans up, and I had to abandon its use."

Molasses amd Vinegar.—We have found that a mixture of molasses and vinegar—three parts of the former to one of the latter—can be used to good advantage for the destruction of the moths. The materials should be well stirred and placed about the mill in shallow pans or dishes in the evening just before closing. This substance lasts longer than either the flour paste or the vinegar and water, and does not require as much attention. The moths are attracted to it and are caught in the sticky substance.

Fly-paper.—This paper, known also as "tangle-foot," is rather expensive for use in mills, but we have used it with very good results, catching from fifty to a hundred moths on a single sheet in one night. Care should be taken to place the paper in such places as are likely to be visited by the moths for the deposition of their eggs; for example, on piles of flour in bags.

Coal-tar.—This substance has been used to good advantage by smearing it over large pieces of heavy paper and placing them about the mill. The tar dries out rapidly, and must be renewed at least every twenty-four hours. Coal-tar has also been used, with surprisingly good results, for painting rough walls and other places about a mill, thus stopping up cracks where insects would find lodgement and escape unnoticed.

Coal-tar and Vaseline.—We have tried an equal mixture of these two substances with no better results than with coal-tar alone, except that paper smeared with this mixture, not drying out so rapidly, does not need to be renewed so often.

Hand-picking.—Many millers whose premises have been overrun with the flour moth, have kept it in check somewhat by "hand-picking." For this purpose extra help was employed, which added materially to the operating expenses of the plant. One firm in California kept several boys and one man at work several months killing moths in this manner. This method was, however, finally abandoned, and the mill was fitted up with steam pipes; and now one man does the entire work of sweeping, cleaning, and inspecting all incoming material, of whatever kind, and the moth is kept in such subjection that it gives them little or no inconvenience.

Hay Ropes.—I have already referred to the outbreak in Germany in 1858 on page 22. The miller who told me of this instance said the moth was most abundant during the month of June. This, he says, was the haying season, and long ropes of newly mown hay were made and placed about the mill in coils. He says the moths collected in great numbers in these coils, which were gathered up and burned each week.

High and Low Temperatures.—It has been ascertained by experiment that a temperature of 120° to 130° Fah., continued for two or three hours, is fatal to the larvæ in flour or other manufactured products, and if continued five or six hours is destructive to the eggs. In case whole grain is found infested, a very much greater heat is permissible. Wheat has been subjected to a temperature of 150° Fah. for a short time without destroying its germinating power.

As before mentioned, infested mills in Canada have been filled with steam and then thrown open, the cold winter air, as it penetrated every part of the mill, destroying many larvæ and pupæ. Cold weather, however, has little or no effect on the larvæ when left undisturbed in their silken tunnels.

The following references to the places of publication of the more important articles that have been written on the Mediterranean flour moth are given below in convenient, compact form, usually with an indication of the character of the contribution. The articles marked with an asterisk I have not seen.

BIBLIOGRAPHICAL LIST.

1879.

1. ZELLER, P. C.—Stett. Ent. Zeit., 1879, pp. 466–471.

Original description of species, with notes on outbreak.

1881.

2. SNELLEN, P. C. T.—Tijdschr. voor Ent., 1881, pp. 20–22.

Mention of Prof. Zeller's paper (1879).

1884.

3. GIRARD, MAURICE.—Bull. Soc. Ent. France, 1884, pp. lxxiii, lxxiv.

Note on ravages of the moth at Lodelinsarte, Belgium.

4. KARSCH, F.—Ent. Nachr., May, 1884.

Record of the appearance of the moth on the lower Rhine.

5. PREUDHOMME DE BORRE, A.—Compt. Rend. Soc. Ent. Belgique, July 5, 1884.

An account of injury done in a noodle factory in Belgium.

1885.

6. ENTOMOLOGISCHE NACHRICHTEN, 1885, pp. 46, 47, 239, 240.

Editorial mention of the appearance of the flour moth at Bremworde.

Review of a communication by Prof. Landois to the *Braunschweiger Tageblatt.*

7. SNELLEN, P. C. T.—Tijdschr. voor Ent., 1885, v. 28, pp. 237–251.

An illustrated article of considerable importance.

1887.

8. LINTNER, J. A.—Thirty-ninth Ann. Rep. N. Y. State Mus. Nat. Hist., pp. 99, 100.

Reply to a letter from Mr. A. Seigel, German Consul-General at New York City, asking information regarding the flour moth.

9. THOMPSON, W.—The Entomologist, 1887, v. 20, pp. 66, 139.

Finds this insect—first recorded (p. 66) as *Myelois ceratoniæ*—feeding on rice cones.

10. TUTT, J. W.—The Entomologist, 1887, v. 20, p. 212.

Records breeding of the adult from larvæ found feeding in a cargo of flour at the London docks, and gives short account of larval feeding habits.

11. COCKERELL, T. D. A.—Proc. S. Lond. Ent. Soc., 1887, p. 58.

Exhibition of larvæ, with statement that they lived in flour which had been shipped from America to Trieste, and thence to London. (See No. 20.)

12. BARRETT, C. G.—Ent. Month. Mag. 1887, v. 23, p. 255.

Account of breeding experiments, with brief description of moth and note of distinctive characters.

13. KLEIN, S. T.—Trans. Ent. Soc. Lond., 1887, pp. lii–liv.

Record of observations made in a large warehouse in the east end of London, in which the discovery of a flour-moth parasite (*Bracon brevicornis*) is mentioned.

*14. ——— The Miller (London) 1887, p. 446.

Full details concerning a lot of flour from Trieste infested with larvæ. Reference also made to the parasite noted above.

*15. ———Mark Lane Express (London) Nov. 14, 1887.

A note regarding the introduction of the flour moth into England.

16. ENTOMOLOGIST'S MONTHLY MAGAZINE, 1887, p. 163.

Editorial notice of paper read by Mr. Klein before the Entomological Society of London. (See No. 13.)

17. GEIKIE, A.—Proc. County of Middlesex Nat. Hist. and Sci. Soc. for Nov. 8, 1887.

Note on the destruction of the flour moth by a parasite (*Bracon brevicornis*).

*18. ADKIN, R.—Field, 1887, p. 829.

*19. ——— Proc. S. Lond. Ent. Soc., 1887, p. 20.

1888.

20. COCKERELL, T. D. A.—The Entomologist, Nov. 1888, p. 279.

States that the larvæ exhibited before the South London Entomological Society in June, 1887 (see No. 11), although found in flour which came from America, are supposed to have come from some infested Trieste flour which was in the same warehouse.

21. POULTON, E. B.—Trans. Ent. Soc. Lond., Dec., 1888, pp. 598, 599.

Under the caption "The Determination of Sex in certain Lepidopterous Larvæ," gives an interesting item concerning the larva of *Ephestia kuehniella.* Demonstrated by observation and experiment that larvæ with dark spots on the dorsal surface of the fifth abdominal segment always developed as males, and that the spots are embryonic testicles.

22. BROCCHI, P.—Bull. du Ministére de l'Agriculture, 1888.

A brief summary of the past history of the pest, with mention of remedies.

1889.

23. ORMEROD, E. A.—Insect Life, Mar., 1889, v. 1, p. 314.

A letter to Dr. C. V. Riley regarding this pest in England.

24. ——— Twelfth Rep. Inj. Ins. 1888, pp. 66–72.

An interesting account of the outbreak of the flour moth in England.

25. RILEY, C. V., & HOWARD, L. O.—Insect Life, May, 1889, v. 1, p. 355.

Mention of *Ephestia kuehniella* in connection with a review of Miss Ormerod's Twelfth Report.

26. BRYCE, P. H.—Bull. I., Provincial Bd. Health, Ont. (Issued by Ont. Dept. Agr., Oct., 1889.)

An important article concerning the Canadian outbreak.

27. RILEY, C. V., & HOWARD, L. O.—Insect Life, Dec., 1889, v. 2, pp. 166–171.

Summary of history and literature, with original notes and observations.

28. FLETCHER, JAMES.—Insect Life, Dec., 1889, v. 2, pp. 187–189.

A letter to Dr. Riley regarding the Canadian outbreak.

1890.

29. FLETCHER, JAMES.—Rep. Minister Agr. [Ottawa], 1889, App., pp. 73–79.

A review of Dr. Bryce's Bulletin (see No. 26), with much additional information regarding the Canadian outbreak.

30. FLETCHER, JAMES.—Rep. Ont. Ent. Soc., 1889, pp. 95–100.

A general review of the history of the flour moth in Canada.

31. RILEY, C. V., & HOWARD, L. O.—Insect Life, Jan.–Feb., 1890, v. 2, p. 260.

Mention of the rearing of *Chremylus rubiginosus* from *Ephestia kuehniella.*

32. ORMEROD, E. A.—Thirteenth Rep. Inj. Ins., 1889, pp. 49–54.

A partial review of matter in her Twelfth Report concerning the flour moth, with many other notes upon it.

33. BRYCE, P. H.—App. Bull. I., Provincial Bd. Health, Ont. Oct. 15, 1890.

A circular letter urging millers and dealers to take active steps to eradicate the flour moth.

34. PATTON, W. H.—Insect Life, Nov. 1890, v. 3, pp. 158, 159.

Under caption "Notes upon *Ephestia interpunctella* (Hübn) Zeller," both *E. kuehniella* and *Tinea zeæ* are listed as synonyms of *E. interpunctella.*

35. RILEY, C. V., & HOWARD, L. O.—Insect Life, Nov. 1890, v. 3, p. 134.

Dissent from Patton's views (See No. 34) believing *Ephestia kuehniella* to be a distinct species.

1891.

36. HULST, G. D.—Trans. Am. Ent. Soc., 1890, v. 17, pp. 198–200.

Some notes on *Ephestia kuehniella* in monograph of North American Phycitidæ.

37. FLETCHER, JAMES.—Rep. Minister Agr. [Ottawa], 1890, App., pp. 168–171.

General summary concerning the Canadian outbreak.

38. ORMEROD, E. A.—Fourteenth Rep. Inj. Ins., 1890, pp. 49–54.

A general review of the English outbreak, for the year 1890, with much additional information on the subject.

39. RILEY, C. V., & HOWARD, L. O.—Insect Life, Apr. 1891, v. 3, p. 333.

Mention of a species of Ephestia (either *kuehniella* or *interpunctella*) in corn from Venezuela.

1892.

***40.** COCKERELL, T. D. A.—Daily Gleaner, Aug. 11, 1892; Tri-Weekly Budget, Aug. 11, 1892; Jamaica Post, Aug. 13, 1892.

Reprint by the above Jamaica newspapers of a circular letter announcing the appearance in Jamaica of what was at first supposed to be the flour moth, but which proved to be *Ephestia desuetella.*

*41. DECAUX, C.—Arch. de Med. et de Pharm. Militaire (France,) No. 8, 1892.

Notes and record of experiments with *Ephestia kuehniella.*

*42. ——— Ann. Soc. Ent. France, v. 62 (Bull.), pp. ccii, cciii.

A communication concerning *Ephestia kuehniella* to the *Congrés des Sociétés Savantes,* notice of which is published in the *Annales* above cited.

*43. ——— Ann. Soc. Ent. France, v. 62 (Bull.), pp. ccii, cciii.

A communication to the *Académie des Sciences* (France), concerning *Ephestia kuehniella,* referred to in the above *Annales.*

44. RILEY, C. V., & HOWARD, L. O.—Insect Life, Nov. 1892, v. 5, p. 141.

Reference to the appearance of *Ephestia kuehniella* in Jamaica (erroneously reported; see No. 40) and in flouring-mills in San Francisco, Cal.

45. ADKIN, R.—The Entomologist, 1892, v. 25, pp. 53, 54.

A short article on the English outbreak, and original notes.

46. JOHNSON, W. G.—Sacramento Record Union, Dec. 5, 1892; Santa Cruz Surf, Dec. 5, 1892; Los Angeles Times, Dec. 5, 1892; Santa Barbara Morning Press, Dec. 8, 1892.

An "emergency circular" (for copy see p. 33.) reprinted in the California newspapers.

47. ——— San Francisco Call, Dec. 6, 1892.

Matter furnished a reporter in an interview concerning *Ephestia kuehniella.*

48. ——— Stockton [Cal.] Mail, Dec. 12, 1892.

A short account of the flour moth with reference to its occurrence in California.

49. RAGONOT, E. L.—Ann. Soc. Ent. France (Bull.) Dec. 28, 1892, p. cclxxiv.

Remarks on the origin of *Ephestia kuehniella* and on its zoölogical position.

1893.

50. JOHNSON, W. G.—Milling (Indianapolis, Ind.) Jan., 1893, v. 2. pp. 177–180; reprinted in American Miller (Chicago) Feb., 1893, v. 21, p. 119.

Brief summary of past history, and notes on the California outbreak.

51. DECAUX, F.—Ann. Soc. Ent. France (Bull.) 1893, p. xii.

Remarks upon the distribution of *Ephestia kuehniella* and upon the experimental work of Dr. C. Decaux.

52. RAGONOT, E. L.—Ann. Soc. Ent. France (Bull.), 1893, pp. xii, xiii.

General remarks upon the habits of *Ephestia kuehniella* and on means for its destruction.

53. RILEY, C. V., AND HOWARD, L. O.—Insect Life, Apr., 1893, v. 5, p. 276.

Mention of the article by W. G. Johnson in "American Miller," for February, 1893 (see No. 50), and notice of Mr. Danysz's preliminary studies on the flour moth.

54. DANYSZ, J.—Mém. du Lab. de Parasitologie Végétale de la Bourse de Commerce, v. 1, 60 pp.

This is perhaps the most important article that has been published on the flour moth.

55. ——— Ann. Soc. Ent. France, (Bull.), 1893, pp. clxxviii, clxxix.

Note on the pigment spots of the larva.

56. DECAUX, F.—Rev. Sci. Nat. Apliquées, 1st Semestre, 1893, pp. 220–225.

An article with illustrations, treating of the habits of the flour moth and of means for its destruction.

57. RILEY, C. V., & HOWARD, L. O.—Insect Life, July, 1893, v. 5, pp. 290, 291.

A review of Mr. Danysz's pamphlet, mentioned above.

58. ——— Insect Life, July, 1893, v. 5, p. 350.

Announcement that the insect reported from Jamaica as *Ephestia kuehniella* (see No. 44) proved to be *E. desuetella* Walker.

59. ——— Insect Life, July, 1893, v. 5, p. 353.

Mention of Mr. Ragonot's views concerning the origin of *Ephestia kuehniella.*

60. ——— Insect Life, Nov., 1893, v. 6, pp. 44, 45.

Note concerning Mr. Danysz's observations on the pigment spots of *Ephestia kuehniella.*

61. BRUNER, LAWRENCE.—Rep. Neb. State Bd. Agr. 1893, p. 401.

A short, compiled, illustrated article.

1894.

62. McCARTHY, G.—Bull. 96, N. C. Agr. Exper. Station, Jan. 1894, p. 64.

A notice regarding *Ephestia kuehniella* in which it is said to be present in North Carolina.

63. RILEY, C. V., & HOWARD, L. O.—Insect Life, Feb., 1894, v. 6, p. 221.

Ephestia kuehniella listed as having been found in meal, bran, and cakes in the Mexican exhibit at the World's Fair (Chicago).

64. RILEY, C. V., & HOWARD, L. O.—Insect Life, May, 1894, v. 6, p. 355.

Reference to Mr. E. B. Poulton's paper on the embryonic testicles of the larvæ of *Ephestia kuehniella.* (See No. 21.)

1895.

65. JOHNSON, W. G.—Am. Miller, Jan., 1895, v. 23, p. 33.

Mentions finding *Tribolium ferrugineum* feeding upon the larvæ of *Ephestia kuehniella* in a California mill.

66. AMERICAN MILLER, Jan., 1895, v. 23, p. 50.

Editorial notice of the proposed work on the flour moth in Eastern United States.

67. JOHNSON, W. G.—Am. Miller, Mar. 1895, v. 22, p. 198.

A preliminary account of experiments with the flour moth, with notes on observations.

68. ———Am. Miller, May, 1895, v. 23, p. 347.

Announcement of the appearance of the flour moth in New York State.

69. AMERICAN MILLER, May, 1895, v. 23, pp. 367, 368.

Editorial comments on the New York outbreak mentioned above, and (p. 368) a note on the flour moth quoted from Prof. Landois.

70. RILEY, C. V., & HOWARD, L. O.—Insect Life, July, 1895, v. 7, p. 416.

Reference made to the article (see No. 68) announcing the appearance of the moth in New York State, and recommendations made to millers.

71. CHITTENDEN, F. H.—Year-book of the U. S. Dept. of Agr. for 1894, pp. 283–285.

A short, illustrated, somewhat popular account of the flour moth, with notes.

72. JOHNSON, W. G.—Am. Miller, Oct. 1895, v. 23, pp. 738, 739.

Brief account of the methods used in New York and California in fighting the flour moth.

73. ———Am. Miller, Nov., 1895, v. 23, p. 810.

Notes on the discovery of *Bracon hebetor* Say, a new parasite of *Ephestia kuehniella,*—the first observed in America,—and on a new locality for the moth in Canada.

74. ———Ent. News, Dec., 1895, v. 6, p. 324.

A preliminary note on the discovery of *Bracon hebetor* Say preying upon larvæ of *Ephestia kuehniella.*

75. BURNS, E.—Am. Miller, Dec., 1895, v. 23, p. 910.

A communication from a Pennsylvania miller, giving an account of his three years' experience in fighting the flour moth.

1896.

76. JOHNSON, W. G.—Am. Miller, Jan., 1896, v. 24, p. 32.

A few notes on the flour moth with reference to the new outbreak in Pennsylvania. Illustrated.

77. ——— Can. Ent. Jan., 1896, v. 28, p. 13.

Note on the new outbreak of the flour moth in Canada.

78. ——— Am. Miller, Feb., 1896, v. 24, p. 114.

Answer to a query from a milling firm in Melbourne, Australia.

79. TRELEASE, WILLIAM.—Science, Feb. 14, 1896, v. 3 (n. s.), p. 252; Can. Ent., March, 1896, v. 28, p. 61; Am. Nat. v. 30, p. 258.

Reports that he exhibited at a meeting of the St. Louis Academy of Science, a silk fabric from Mexico, supposed to be the work of the Mediterranean flour moth.

NOTE.—I am in receipt (March 5, 1896) of a package of infested flour from a mill in Saltillo, Mexico, which has been forwarded to me by the editor of the "American Miller." The flour is one mass of web, and contains hundreds of larvæ, pupæ, and dead moths of the Mediterranean flour moth *Ephestia kuehniella*. The material was taken from a flouring-mill, where the moth is doing much mischief.

ADDITIONS AND CORRECTIONS.

Page 22, line 15, for article read articles.

Page 26, line 2 from bottom, for *saperdoides* read *saperdioides*; line 4 from bottom, for *Nodata* read *Nadata*.

Page 28, line 15, for of read for.

Page 64, line 15 from bottom should be in Roman instead of italic type, and should stand as part of the line above.

Page 81, line 6, for Anomæa read Anomœa.

Page 98, line 1, for 91 read 80.

Page 100, *dele* heading *Experiments with Barriers and Traps* and Nos. 81-91 following.

Page 102, *dele* italic middle heading.

Page 159, just above middle heading "1889" insert as follows:

THAXTER, ROLAND.—The Entomophthoreæ of the United States. (Mem. Bost. Soc. Nat. Hist., v. 4, No. 6.)

Monographic account, with eight plates contaning 429 figures.

Page 161, under middle heading "1890," insert as follows:

BRUNER, LAWRENCE.—[Fungoid Disease of Box Elder Bug.] (Bull. Neb. Agr. Exper. Station, No. 14, p. 130)

Disease probably due to the same Entomophthora that attacks the chinch-bug.

Page 204, line 6 from bottom, for 1892 read 1893.

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